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PRINCIPLES OF
CORRECT THINKING

PRINCIPLES OF CORRECT THINKING

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PATTERSON
PRINCIPLES OF CORRECT THINKING

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PREFACE

A beginning course in logic may be designed to reach any one of several different objectives. One of these is discipline in the matter of formal reasoning or, in other words, training in mental gymnastics. Another one is an adequate preparation for the reading of advanced and technical works in the fields of mathematics and philosophy. A third one is an introduction to the study of the metaphysical problems involved in a discussion of the nature of truth. And besides these there are other objectives. All of them express purposes that are worthy and they may be pursued with profit by students who have these particular interests.

There is, however, another objective for the elementary course in logic. Though it does not exclude entirely those mentioned, the main purpose of this objective is more in line with wider interests and problems of students. The chief aim in this case is the presentation of logical principles so that these may be regarded as instruments for the solution of all kinds of problems. From this point of view, the course in logic may be considered as a valuable preparation for courses in any field of science. The problems of science, as well as many other problems which occur in everyday life, will come to be recognized as problems in logic, inasmuch as logical methods will be found necessary for their solution. It is for the purpose of reaching an objective of this kind that this text book has been prepared.

If the course in logic is to be regarded as a preparation which will enable the student to do better work in other fields of science, and if this objective is to be attained within a single semester, there are certain limitations which must be recognized. This will explain, at least in part, the omission from this book of any references to such topics as symbolic logic, discussions of logical theory, and other recent and important developments within this science. It is recognized that these topics are highly significant for the science of logic

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and should be included in any advanced or thorough treatment of the subject. But they are not essential for a beginning course.

To accomplish the objective which has been indicated for this book it has seemed necessary to include a brief and precise statement of the most essential elements of traditional deductive logic. A more complete account has been given of the so-called inductive methods. With reference to the book as a whole it may be said that an attempt has been made to give particular emphasis to each of the following points: (1) Any complete act of thought includes three elements which may be designated by the terms scientific imagination, deductive reasoning, and verification through the use of the inductive methods. (2) These three elements are interdependent. They should be regarded not as different kinds of reasoning but as different phases of the one reasoning process. (3) It is through the correct use of each one of these three elements that the achievements of science and the solution of other human problems have been obtained.

The use of concrete examples for the purpose of illustrating logical procedure is probably the most distinctive characteristic of this book and it is only in connection with the use which has been made of these examples that any claim for originality can be made. In selecting these examples care has been taken to secure material that is comparatively free of technical terms, and which will, for that reason be intelligible to students having only a slight acquaintance with the particular field from which any example has been taken. The problems have been presented with a sufficient amount of detail to enable the reader to understand fully the nature of the investigation as well as the logical procedure involved in reaching a solution.

Grateful acknowledgment is made of the help rendered by publishers, colleagues, students, and friends in the preparation of this book. The author is particularly indebted to the Burgess Publishing Co. of Minneapolis for a mimeographed edition of the book. This edition made it possible to try out the book in several classes and to profit by the criticisms of students and teachers before going into print. Thanks are

also due to The Macmillan Co. of New York for permission to use materials which were included in a former book entitled *Problems in Logic.* Permission to use copyrighted materials has also been granted by the Thomas Y. Crowell Co., D. Appleton-Century Co., Doubleday, Doran & Co., The J. B. Lippincott Co., Little, Brown & Co., and Col. J. H. Wigmore the author of *Principles of Judicial Proof.* For all of these permissions the author is deeply grateful.

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CHARLES H. PATTERSON

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PRINCIPLES OF
CORRECT THINKING

CHAPTER I

INTRODUCTION

Definition and Scope. Logic is concerned with order. It has to do with the systematic arrangement of things. As a science it aims at the discovery of those principles of order that are included in the whole field of human knowledge. Hence the field of logic includes every branch of organized knowledge. The principles of logic are involved in the relationships that exist between the members of any group of organized phenomena.

This is true whether the phenomena in question have any existence in the physical world or not. The science of mathematics, for example, may deal with the subject of infinite numbers or with imaginary numbers. Neither of these corresponds to objects which exist in the physical universe. Nevertheless there are certain fixed and definite relations which hold between these numbers, and for this reason they belong to the field of logic. Physical sciences are like mathematics in so far as they deal with the logical relationship of concepts to one another. But they differ in that it is necessary in the case of these sciences to show a correspondence between the concepts and their relations and the objects which exist in the physical world.

Thus we see that logic has a two-fold purpose in the case of physical sciences as compared with the single function which it performs in the field of mathematics. In the case of the latter, ideas are logical if they are consistent but they must correspond to objects in the physical world.

Logic, however, has to do with other fields of knowledge as well as with mathematics and physics. It includes, for instance, the principles of arrangement that are involved in the construction of a bridge or a building. It is concerned with the selection and ordering of the parts that go to make an exciting story or novel. It deals with the evaluation of human conduct, with the principles involved in running a business, and with the phenomenon of religion. In short the field of logic includes all the orderly arrangements of the universe. Logic would have no place in a world of chaos, but, wherever there is order, or in other words a systematic arrangement of parts, there its principles are applicable.

Logic may be defined as *the science of correct thinking.* All sciences have to do with a statement of general principles and their relation to particular facts of experience. The difference between the various sciences is due to the respective fields in which these principles and relationships are discovered. The science of geology differs from psychology because the material studied in one case is the earth and in the other case it is the mind. So far as the reasoning process in the two fields is concerned there is no essential difference. The science of logic has for its particular field the principles of correct thinking. Correct thinking is involved in all fields of science and of philosophy and all other branches of organized human knowledge. It is with these principles of thinking, wherever they may be found, that logic is concerned.

In connection with the definition of logic, it may be well to point out that the subject may be viewed either from a *structural* or from a *functional* point of view.

According to the structural conception, logic is concerned with the orderly or systematic arrangements which may be found in things. This means that it is a science the primary purpose of which is the discovery of order as it exists in the objective world. On the other hand, a functional point of view is implied in the statement that logic is the science of correct thinking.

According to this conception, the purpose of logic is not the discovery of an objective order that exists in things but rather an analysis of the propositions which we use in thinking, together with a clarification of their meanings.

There is no agreement among logicians of the present day as to which one of these conceptions should prevail, although the tendency among many recent writers in the field is in the direction of the latter conception. Since this book is for beginners no attempt is here made to defend one or the other of these two points of view or to present the materials of the course from one point of view exclusive of the other.

Logic has sometimes been defined as an art. It has been called *the art of correct thinking*. The difference between a science and an art is that one has to do with knowing and the other with doing. Obviously the two are closely related. To carry on any kind of work successfully one must have considerable knowledge. He must know the character of the thing with which he is working and he must understand the laws that have to do with its use. Some scientific knowledge is a prerequisite for any of the arts. On the other hand most if not all of our scientific knowledge can be used for the accomplishment of some purpose. The correct use of knowledge for the achievement of some end may properly be called an art.

Logic is then from one point of view a science and from another point of view it is an art. But since the principles of correct thinking are useful only as a means of determining whether or not there are any mistakes in the reasoning that has been employed, it is only in the negative sense that logic may properly be called an art. In so far as it is an art, it is the art of detecting fallacies. But it is as a science rather than an art that logic gives us the principles of correct thinking and shows how these principles are related to the particular problems under discussion.

Logic and the other sciences. Since logic is defined as the science of correct thinking it follows that it is closely related to every other field of science. Dr. Bosanquet in his *Essentials of Logic* says that this particular branch of knowledge may be called "the science of the sciences." By this statement he means that logic is the science that deals with the methods of thinking employed by all the sciences. This close relationship between logic and other sciences, he further points out, is indicated by the name which many of these sciences bear.

The science of psychology, for example, is a combination of two elements. It includes particular facts about the mind or *psyche* and the principles of logic (indicated in the name by *logy*) by which these particular facts are arranged and interpreted. All sciences are examples of applied logic. Geology is the science which results from applying the principles of logic to the study of the earth. Anthropology is the application of logic to the study of man. Biology is logic applied to the study of life ; physiology is the same for the study of the human body, and so on for all the rest of the sciences.

This being true we can readily see that the problems of any particular science are from one point of view problems in logic. The bacteriologist studying a typhoid fever epidemic must use logical principles to find the source of contagion. The chemist must think logically in order to discover the laws that have to do with the behavior of the elements that he is studying. The lawyer has a problem in logic when he tries to determine the correct conclusion on the basis of the evidence that has been presented. And the same is true for the scientist who is working in any other field. Obviously no one can be a good scientist unless he is first of all a good logician. This does not mean, however, that it is first of all necessary for him to study logic as a separate science. Many scientists are not familiar with the terminology employed in an elementary logic text-book, and yet they are very successful in their own fields. But in these cases their knowledge of logical principles has been obtained indirectly. They have discovered for themselves the methods of thinking which yield sound results, and they are able to apply them. It is possible for any one to master the principles of logic by studying the methods of thinking employed in any field of science. However there is a distinct advantage to be gained by studying first the science of logic, since in that case the methods of correct procedure are studied directly rather than indirectly.

Besides this relationship which logic holds to all sciences in general, there are other ways in which it is related to certain sciences in particular. Psychology, for example, is a science which deals with the entire field of mental phenomena. And since correct thinking is one type of mental phenomena, logic has sometimes been regarded as a part of the science of psychology. But, granting that these two sciences do have something in common, this is not an adequate statement concerning the nature or function of logic. For one thing, it implies only a functional conception of the field and omits any reference to the structural point of view. Again, there are differences between the two sciences which are not included in this statement. It is true that psychology does include within its field the mental processes which are involved in correct thinking, but it also includes materials which belong to every other field of knowledge.

Every science is the result of thinking and the body of knowledge which pertains to any particular field is made up of ideas. Yet thinking and ideas are mental phenomena and as such they belong to psychology. So while logic may be considered as a part of psychology, it belongs to this science only in the sense in which every other science belongs to it. But even though we are dealing with that type of mental phenomena known as correct thinking, there is a real difference in the way in which this subject is approached by logic and by psychology. The psychologist is interested in thinking as one of the modes of human behavior. He is concerned with an accurate description of the mechanisms that are involved in thinking. He explains not only correct thinking but erroneous forms of thinking as well. His purpose is to describe what takes place within the human body when an individual thinks.

The logician, on the other hand, is not concerned with a mere description of the thinking process. His interest is in the relationship between types of thinking and truth. Ideas are for him either true or false. They are true if they coincide with the world of objects existing outside our individual minds and false if they do not.

Grammar is another science which has something in common with logic. Grammar has to do with the construction of sentences and the proper use of words. Thinking is necessarily associated with the language by which it is expressed. Neither one could function properly without the other. Clear thinking is necessary if one is to express his thoughts so that another can understand them. And it is equally true that careful and precise statement of one's thoughts is an aid to clear thinking. But the main objectives of these respective sciences are quite distinct.

The grammarian is concerned primarily with the proper use of words to express certain definite meanings. He deals with the principles that are involved in the proper construction of a sentence, and with the appropriate use of the various forms of speech. But the logician is concerned chiefly with the truth content of the propositions which he uses. He aims at a consistent interpretation of the facts which are presented to him.

Logic may also be regarded as one of the divisions of philosophy. Philosophy is, at least from one point of view, a synthetic subject which includes within its scope all fields of human knowledge. It seeks to interpret the results which have been obtained in the various sciences by making clear the relationships which they sustain to each other and to the universe as a whole. To do this, philosophy must include among its functions an examination of the assumptions on which the sciences are based. It must also make clear the meanings that are implied in these assumptions and it must determine the grounds or bases of their validity.

In this connection logic is to be understood as an essential part of the field of philosophy. It is an instrument for determining the validity of any assumption or theory which may be under consideration. It may be added that logic deals with the thinking processes that enable us to arrive at truth. But the question concerning the nature of truth, or, in other words, its relation to ultimate reality is a problem of philosophy. This means that it is a question which can be answered only in the light of one's views about the universe as a whole.

Practical Value of Logic. In the first place a knowledge of the principles of logic means greater efficiency. It means a saving in time and energy and an increase in one's ability to solve the problems at hand. This is true regardless of the field in which one may be working. A physician, for example, who is about to diagnose a case will be more likely to reach the correct solution of his problem and he will be able to do it with less effort and in a shorter time if he is first of all familiar with the logical principles involved in the exclusion of irrelevant factors and in drawing correct inferences from the data that he has observed. A chemist will certainly be better prepared to discover and apply the laws that have to do with the behavior of elements if he knows the logical principles involved in the construction of a scientific experiment and if he knows how to determine what conclusions are warranted by the particular facts in the case. The historian must employ logical principles in the evaluation of the data which he studies, and it is clearly evident that a knowledge of the principles which he must use will add greatly to the efficiency with which he works. And what is true in the fields of medicine, chemistry, and history in so far as the practical value of a knowledge of logic is concerned, is equally true of all other fields.

But aside from the way in which it increases efficiency there are other values which belong to the study of logic. The person who knows the requirements of correct thinking has an adequate measure for evaluating the work done in fields other than his own. The writer recalls an incident that took place a few years ago at a meeting of a university faculty. A professor from the classics department had spoken in vigorous condemnation of a recently published book in the field of chemistry. The book, he maintained, was filled with "tommyrot" from beginning to end and should never have been placed upon the market. Yet he confessed before he had finished with his speech that he had never taken a course in chemistry. Well, it might be asked, if he had never taken a course in chemistry how did he know whether or not this book was filled with "tommyrot"? The answer is perfectly clear. The professor of classics did know the requirements of correct thinking. He was a master of scientific method and though his field was classics and the book that he was criticizing had to do with chemistry, it was easy enough for him to see that sound scientific procedure had not been followed by the author of the book. The author had cited facts and had drawn conclusions from them, but since his conclusions could not be drawn logically from the premises, his book had little if any scientific value. A mastery of the principles of logic will then enable an individual to evaluate, with some degree of accuracy, the worth of books, articles, or addresses that have to do with fields of knowledge other than his own.

Perhaps there is no better way of demonstrating the practical value to be gained from a study of logic than by showing what alternatives must be accepted in case the criteria which this science affords be ignored or rejected. One of the alternatives to logical thinking is the acceptance without criticism of some established authority and the refusal to accept anything not in accordance with it. This is a method of procedure which many people have followed. During the Middle Ages it was the dominant method found in the colleges and universities. Even today many accept it as a method to be followed in some fields although they strongly oppose its use in other fields. But the acceptance without criticism of some authority gives no one a guarantee of truth. Authorities have often been found to be wrong. The acceptance of the authoritarian idea is always a barrier to progress. And besides, the question of what authority one should accept is one that cannot be settled by the authority itself.

When logic is interpreted so as to include the proper use of experimentation we may say that the method of trial and error is another one of the alternatives to logical thinking. This method finds illustration in the way in which lower animals try to solve their problems. As an example, one may cite the way in which rats find their way out of a maze or the devices used by chimpanzees and apes in order to secure their food. The animal can profit but little from his previous experience and he is unable to make use of the experiences of others. He has no power of analysis and no way of predicting what is likely to follow from the operation which he performs. He must try first one thing and then another until he finally hits upon some method that gives him the result which he desires. His procedure is necessarily slow and exceedingly wasteful of time and energy. And it is only the simplest type of problem that he is able to solve at all. Human thinking has great advantages over this method. By making an analysis of the particular problem at hand one narrows at once the range of things to be tried out. By comparing the several factors in the case with past experiences he narrows the field still more. And while he can never get away entirely from the procedure of trial and error, he can do most of this work mentally, and by thus avoiding useless experiments he can achieve results much sooner than would otherwise be possible.

Any account of the practical value of a study of logic would be incomplete if some reference were not made to that emotional factor in human life which may be characterized as a passion for truth. The results of the application of scientific methods have been many and various and the benefits which have accrued to mankind from them are generally recognized. But no achievement of science has surpassed in real worth the development of what may be called the spirit of science. Those who possess this spirit place the getting of truth ahead of everything else. For this end they are willing to sacrifice prejudice, give up preconceived ideas, and change their minds whenever the evidence indicates that they have been in the wrong. The spirit of science is indicative of a desire to see both sides of a question, to take into account all the relevant facts and to draw only those conclusions which the facts warrant.

The true spirit of science is always in opposition to that of dogmatism and intolerance. And if the objection be made that the point which we are now discussing belongs to the field of morals rather than logic, it may be answered that these two fields are more closely related than is generally supposed. All scientific procedure is based upon the moral principle of telling the truth. And in the field of ethics there is nothing more significant than the moral obligation to think correctly.

The Discovery of the Principles of Logic. In order to discover the principles that are involved in correct thinking there are two things that a person must do. One of these is to make an analysis of his own thinking. Having faced some particular problem and having obtained a correct solution of it, he can by introspection discover the methods which he used to obtain the result. Of course he will not learn very much about the principles of logic until he has studied the methods of thinking that he has used in solving many kinds of problems. But with a large number of instances under consideration it will be possible to find some principles that have always been used whenever correct results were obtained. Obviously the degree to which any individual can discover the principles of logic from a study of his own mind will depend upon the range and quality of the thinking which he has done as well as upon his ability to make accurate introspections.

The other thing that must be done, if one is to discover the principles of logic for himself, is to take careful account of the successful thinking of others. An analysis of one's own thinking is necessary but it does not go far enough. Logic has to do with the whole range of human thinking. Hence a complete understanding of its principles can be derived only when one takes into consideration all that thinking has accomplished. But to survey adequately all the examples of thinking in the course of human history is too vast an undertaking for anyone to attempt. However it is possible to make a classification of the various types of thinking or in other words the different kinds of problems that have been solved. When this is done one can study thoroughly the thinking involved in typical examples of each class.

Another way of stating the matter is to say that the materials for the study of logical methods are to be found in the great body of scientific knowledge that is everywhere accepted. Astronomers after studying the movements of heavenly bodies have announced the laws governing these movements. On the basis of these laws they have made new discoveries and they have predicted with remarkable accuracy the exact time when various phenomena would occur. Their conclusions have been so completely verified that it is impossible to doubt the validity of the methods of reasoning which they employed. Similar achievements have been accomplished in other fields. Medical scientists have discovered causes of disease and the correctness of their conclusions has been verified when by removal of these causes the disease in question has been eliminated. The results obtained in many other fields of science have been established with an equal degree of certainty. Here then are the materials for the study of logic. Examples of correct thinking can be selected from each of the various fields and an analysis of these will reveal the principles that were involved in the various cases and which must always be followed if correct results are to be obtained.

Steps Involved in the Reasoning Process. As we have stated before, the procedure of correct thinking is essentially the same regardless of the field in which it may be used. Reasoning in the field of law must follow the same principles as reasoning in physics or astronomy. Reasoning in chemistry does not differ in so far as method is concerned from reasoning in psychology or in any of the social sciences. The distinguishing characteristics of these various fields is to be found in the subject matter which is studied rather than in the methods of thinking employed. It is for this reason that the person who has pursued any science to the point where he has mastered the methods of that science is able to judge, with a fair degree of accuracy, the quality of work done in any other field.

Science deals with all sorts of problems. The nature of any specific problem will be determined by the field in which it occurs and by the circumstances that are present in the particular case. But in spite of this wide variety in the nature of problems to be solved there is some degree of uniformity in the method of procedure by which the scientist deals with each one. It is possible to indicate certain stages or steps which are always involved in the matter of problem solving. Three stages can be named. Two of these are characteristic of the work of all sciences, and the third is present in all fields except that of mathematics. These three stages include *scientific imagination* or that process of the mind which is always associated with an awareness of the problem and any hypothesis which may be suggested for its solution, *deductive reasoning* by means of which the implications of hypotheses are brought to light, and verification of the hypothesis by means of the *inductive methods.*

By the first of these stages is meant that function of the mind which grasps a given situation and after recognizing the problem which it involves conceives of some possible or probable solution for it. This part of the process may appropriately be called *scientific imagination.* It is a function that is difficult to analyze and one that can be understood only by those who have had some experience of it. But it is an important factor in scientific procedure, as will be indicated by any thorough analysis of the problem-solving procedure. The statement has frequently been made that the work of the scientist begins with observation of particular facts. From these he derives some hypothesis and then proceeds to determine whether or not his hypothesis is a valid one. The trouble with this statement is that it ignores the fact that observation of instances, if it is to have any scientific value, must be guided by some principle. It is not enough just to observe things in general. One must know what to observe. And in order to know what to observe one must have a definite problem in mind. This will enable him to determine what factors are relevant and consequently what he should look for. The nature of the specific problem and the things to be looked for in connection with its solution are factors that are determined by one's past experiences and by the set of definitions and relations which he has in mind.

The second stage in the process of problem solving is that of deductive reasoning. Its purpose is that of determining the implications involved in the hypothesis which one has in mind. With a given set of definitions and with some idea concerning their relationships it is possible to determine other things which must also be true provided the original hypothesis be true. Inference of any kind is possible only on the assumption that the things with which one is dealing are parts of some system or organized whole. The parts of a picture-puzzle may be assembled provided that there is a picture to which they belong and that the picture will be complete only when all of the parts are properly assembled. With these conditions fulfilled, however, it is possible to determine on the basis of some parts of the picture what other parts will be like. The same is true of any field of science. The particular facts of which the science takes account are analogous to the parts of the picture-puzzle. Hence passage from one set of facts to another involves the assumption that both sets of facts belong to the same system. Whenever one goes from the idea of a system as a whole to some particular part of that system his reasoning is of the deductive type.

One of the best illustrations of this kind of reasoning is furnished by the science of mathematics. To begin with, the mathematician puts forth a set of definitions and axioms. He then proceeds to work out the implications of these by making deductions from them. In this way he develops the whole content of his science. The validity of the conclusions which he draws is determined in each case by showing how they can be derived deductively from the basic assumptions with which he started. This type of reasoning is just as essential for other sciences as it is for mathematics. The sciences that have to do with the nature of the physical world all have their basic definitions and postulates, and it is in part, at least, by making deductions from these that the scientist obtains his hypotheses which must then be verified by comparing the results obtained from them with observed facts.

The third stage in the reasoning process has to do with the verification of hypotheses. It is in connection with this that observations are made of those particular facts that are relevant to the problem under discussion. This process includes the use of what has often been called the inductive methods of reasoning. One of these is the method of simple enumeration or *sampling*. Another one is called the method of *agreement* and has to do with the common factor present in all instances where the phenomenon in question occurs. A third one is called the method of *difference* and is based on a study of instances which illustrate both the presence and absence of the phenomenon. Other methods, including *concomitant variations*, *residues*, and *analogy* may also be used. Of course the complete verification of scientific hypotheses involves more than a use of the methods that have just been named. The conclusions which these methods yield usually have to be subjected to further tests involving a use of deduction, since it is only by making deductions from these conclusions and comparing these with more observed facts that their validity can finally be established.

The study of logic may be divided conveniently into three parts, corresponding to the three stages in the reasoning process which have just been described. This is the basis for the organization of the material presented in this book. Part I deals with scientific imagination, and with the use of terms and their definitions. Part II deals with deductive reasoning, and Part III with scientific verification. But while it is necessary for the purpose of analysis to break up the reasoning process into these parts and to treat each part separately, it must always be remembered that this division is, at least from one point of view, an artificial one. In our actual experience we do not find any one of these three parts functioning by itself independently of the other two. Each one is dependent upon the other two and tends to supplement the reasoning process as it is carried on by them. In other words, the parts are organic to the system of thought which includes all of them.

QUESTIONS AND EXERCISES

1. What is the difference between an art and a science ? What is the particular field of the science of logic ? In what sense is logic an art ? in what sense is it a science ? Distinguish between the functional and the structural conceptions of logic.
2. Explain the relationship between logic and other sciences. What does logic have in common with the science of psychology ? Mention two ways in which these sciences differ. Explain the relationship of logic and grammar and tell how they differ. What is the relationship between logic and philosophy ?
3. What is the practical value of a knowledge of the principles of logic ? What are some of the alternatives to correct thinking ?
4. Distinguish between animal learning and human learning. Show how a knowledge of logical principles makes it possible for one to criticize work in some field other than his own.
5. Explain the case of the scientist who reasons correctly but who has never studied logic.
6. Why is it necessary for one who wishes to know the principles of logic that he make an analysis of his own thinking ? Why is it necessary for him to take account of the work of others ?
7. Explain briefly what is meant by the terms "scientific imagination," "deductive reasoning," and "verification." Show how these three are related in the problem-solving process.
8. Make an analysis of some problem that you have solved pointing out your use of the scientific imagination, deduction, and verification of the results.
9. What is the advantage of a course in logic for a law student ? for a medical student ? for one who expects to do work in history or in philosophy ? for one who does not expect to enter any of the professions ?
10. Give illustrations of different types of thinking and indicate the function of logic with reference to each type.

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PART ONE

SCIENTIFIC IMAGINATION

CHAPTER II

LOGIC AS SCIENTIFIC METHOD

The Aim of Science. "The aim of science," to quote one of the distinguished scientists of our day, "is to describe the impersonal facts of experience in verifiable terms, as exactly as possible, as simply as possible, and as completely as possible. It is an intellectual construction,—a working thought-model of the world." * This statement contains brief references to several of the most important characteristics of science. A somewhat further statement concerning these will now be attempted.

In the first place we are told that the aim of science is a description of phenomena. To many this statement seems at first quite insufficient to characterize the objectives of science. We have been accustomed to think of science as offering us explanations of phenomena rather than a mere description of them. A photograph, we may say, is sufficient to give us a description of things, but the knowledge it reveals is not necessarily scientific. Descriptions of things or of events may be made by individuals who do not have the slightest idea concerning the principles that govern the behavior of the things they have described. How then can we say that the purpose of science is to give us a description of things? The answer to this question is that there are different kinds of description.

Some types or levels of description are not scientific while others are. The description which amounts to nothing more than a photographic reproduction of things differs widely from the description which sets forth the laws or principles by which the behavior of the objects in question are governed. But both are descriptions. If we simply make record of the fact that so far as our observations have gone water rises thirty-two feet in a pump, our description has not reached the explanatory level. But when we explain this same phenomenon by saying that it is due to atmospheric pressure which is so many pounds per square inch, we have only described it in another way. The explanation of falling bodies by reference to the law of gravitation is likewise only a description of the way in which these bodies move. All scientific laws are descriptions of the behavior of phenomena. All explanations are really descriptions. But they are descriptions which reveal the laws or principles operative in the things described and it is in this sense of the term that the aim of science is the description of phenomena.

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* J. Arthur Thomson, "*Introduction to Science,*" p. 56.

The descriptions of science have to do with the impersonal facts of experience. But what do we mean by impersonal facts? From one point of view all the facts and principles of science are personal. They must be recognized and interpreted by human minds and it is only to persons that they are meaningful at all. But it is not from this point of view that the facts of science are said to be impersonal. What the scientist means is that the facts with which he deals must be viewed apart from the emotional and volitional factors of human nature. In making his investigations the scientist must not be influenced by his own desires nor can he allow prejudice or personal bias to direct his observations. He cannot select the facts which support the thesis he has in mind and neglect the facts that contradict it. He must take into account all the facts relevant to his problem regardless of whether or not the conclusion which they support will be pleasing to him. He must suppress all his desires, except of course his desire to find the truth as it exists independent of him. Again the explanations which he offers must always be in terms of secondary rather than primary or ultimate causes. The notion of a divine will or a cosmic purpose does not belong to the realm of science and cannot be used to explain natural phenomena. The scientist can only describe the phenomena of the universe as it appears to him. He cannot answer questions concerning the origin of the universe, the meaning of its history, or the ultimate goal toward which it may be moving.

The explanations of the scientist must always be in terms that are verifiable. This means that the conclusions which he draws must be of such a nature that their validity can be tested by other individuals. The laws or principles of science must be universal or, in other words, they must, once they are correctly understood, have the same meaning for everyone. This means that under any given set of conditions, certain results are bound to follow. In this sense we may say that the goal of all science is prediction. If the scientist can tell what will happen when specified conditions have been fulfilled, then it will be possible for other individuals to meet these conditions and see for themselves whether or not the predicted results actually occur. If they do, the conclusion may be said to have been verified. But there is no other way of determining whether they are correct. Unless the conclusions of the scientist can be put to this kind of a test they have no value, and it is a waste of time even to consider them.

Again we are told that the descriptions of science must be made "as exactly as possible, as simply as possible and as completely as possible." To know the facts that have to do with the problem at hand is one of the fundamental requirements of science. But an exact description of the facts is often difficult to obtain. There are many reasons for this. For one thing, unless the human eye has been carefully trained to do otherwise, it sees only those things that it expects to see. It is easy to confuse the objects that we have seen with inferences which we have drawn from them. And we may not have at hand the necessary instruments to enable us to measure with precision. But only in so far as these difficulties can be overcome, will it be possible for anyone to approach the ideal of science.

The statement that scientific descriptions must be made "as simply as possible and as completely as possible" is a reference to the logical principle known as the "Law of Parsimony." This principle was stated by the medieval philosopher William of Occam in the following manner:

"Entities are not to be multiplied beyond necessity." It means that scientific explanations, if they are to be valid, must be expressed in terms of the smallest possible number of concepts and principles. The principle upon which the law of parsimony is based is set aside whenever it becomes necessary to make exceptions to the general rule in order to explain the particular phenomena in question. The rule or principle which is broad enough to include the so-called exceptional cases along with all the rest of them is to be preferred to the rule which cannot take these special cases into account. Man-made laws which exist for the purpose of controlling human behavior may admit of exceptions. But there are no exceptions to the laws of nature.

To postulate a law of nature and then to make exceptions to this law in order to explain certain facts which seem to contradict it is really to admit that the formulation of the law has not been reached correctly. Of course the principle involved in the law of parsimony is one that cannot be employed too rigidly. There are times when an exact formulation of the law of nature is impossible due to the fact that our information about the objects in question is limited. In these cases the best that we can do is to make an approximation to the law and find some other explanation for the exceptional cases. But these must be held only tentatively and they should always be regarded as no more than approximate statements concerning the real principles that are involved.

And lastly, when we define the aim of science as the construction of a "working thought-model of the world," we mean that the ideas which we have about the world must be of a systematic order. Our ideas must be related to each other in a manner that will represent accurately the order that exists in nature. The logical principle involved here is known as the "Uniformity of Nature." It means not only that the parts of the universe are together, but that they belong together. Nature is an orderly system. Hence it is possible, once we know a part of a given system, to determine, on the basis of this part, something of the nature of the other parts.

Induction and Deduction. Scientific knowledge differs from ordinary knowledge in that it is more nearly exact and is more comprehensive in its scope. The scientist takes a more critical attitude than does the layman. He criticizes carefully not only the opinions of others but his own opinions as well. He gathers his data from as wide an area as possible and then classifies and organizes the material that he has gathered. And, finally, he uses great caution in the matter of drawing conclusions. He wants to make sure that his inferences are in each case fully warranted by the facts at hand. The methods by which his conclusions are obtained can best be known through an examination of actual cases in which scientific work has been done. An analysis of the way in which a lawyer evaluates the evidence before him, or the way in which a competent physician diagnoses a case, or an engineer solves some problem of construction, will reveal the logical methods which scientists must use.

Although the types of inference which are employed in scientific procedure have been classified by different logicians in various ways, we may divide them into two main classes usually known as "induction" and "deduction." Aristotle, who has been called the "father of the science of logic," recognized three types of inference. They were, first, deductive inference or reasoning from universals to particulars; second, inductive reasoning or that type which begins with particular facts and proceeds to a universal statement; and third, analogical inference or the type which goes from particular facts to particular facts. This classification is not however a satisfactory one since the third type overlaps the other two. It is true that analogical reasoning does proceed from particulars to particulars. But between the particulars which constitute the starting point and the particulars that are contained in the conclusion, a universal judgment is always implied. And the conclusion which is reached can never be any stronger than the implied universal judgment which really serves as the basis for it. Hence analogical reasoning should not be considered as a separate type of inference. It is rather a combination of induction and deduction.

As we have stated before, the distinction between inductive and deductive reasoning is to be found in their respective starting-points. When we begin with particular facts and from these draw a universal conclusion, our reasoning is inductive. Deductive reasoning starts with a universal and proceeds to some particular proposition that is implied in it. Inductive reasoning is illustrated in the way in which we arrive at any of our scientific laws. After observing a number of instances in which a particular phenomenon occurs, we formulate the principle or general law that has been illustrated in each one of the instances. Deductive reasoning is illustrated in the field of mathematics when, with definitions and axioms (both of which are universals) as a starting-point, we proceed to show what particular propositions or judgments are implied in them. Each theorem and corollary is proved by showing that it follows logically from the original definitions and axioms and hence must be true if they are true.

If we stop to make an analysis of any well-reasoned argument dealing with concrete problems of experience, we will find that it includes two processes, (1) generalizations based on particular facts or instances, and, (2) inferences drawn from assumptions or generalizations for the purpose of making clear that which was implicit in them but not obvious. The first of these two processes is what we mean by induction, and the second one is what we mean by deduction.

Take, for example, a typical argument concerning the use of the lecture method in colleges and universities. Let us suppose that the author of the argument is trying to prove that this method of instruction is not a good one. A part of his argument will consist of a recital of particular instances in which this method has been used, but with poor results as compared with other instances in which a different method was used. From these cases he will make a generalization to the effect that similar results will be likely to follow whenever the lecture method is used. This will constitute the inductive part of his argument. But, in addition to this, he will also state why, in his judgment, the lecture method is a failure. To do this he will state certain general principles which constitute a part of his philosophy of education, and, by making clear the implications which are contained in these, he will show that his conclusion concerning the usefulness of the lecture method is in harmony with his general assumptions or principles. This constitutes the deductive part of his argument.

Again, we may take the example of an argument used to prove that any use of alcoholic beverages is detrimental to one's health. On the inductive side we will find an array of facts concerning individuals who have used alcohol and other individuals who have not used it. Perhaps a record will be given of actual tests made with reference to such physiological factors as the number of white corpuscles in the blood, the effect of alcohol in varying amounts on muscular action, etc. In addition to these data the author of the argument will present other facts that have to do with psychological factors. He will cite actual experiments that have been performed to test the action of alcohol on sensory acuity, reaction time, the memory span, attention control, emotions, and the reasoning processes. From these data he will make a generalization to the effect that the use of alcohol always carries with it a tendency to injure one's health. On the deductive side, the argument will contain a number of generalizations that have been reached by eminent scientists. From these generalizations, the one who is presenting the argument will proceed to bring to light their implications and to show that these are in harmony with all the facts which he has presented in his account of particular cases.

But though we distinguish between these two types of inference, we should always bear in mind that the distinction is somewhat artificial. The two types are mutually interdependent. The universals that are reached through induction need to be verified, and the only way that this can be accomplished is by making deductions from them and then comparing these deductions with observed facts. Hence we may say that inductions are dependent upon deductions in order to determine the validity of the conclusions reached. And the reverse is also true. We have said that the starting-point in the deductive procedure is a universal proposition.

But the question may be asked, "Where do we get these universals?" The answer is that we obtain them through inductive processes. We get them by taking into account particular facts of experience. Whenever these universals are challenged we can appeal only to our particular experiences in support of them. Thus we see that our deductive processes are likewise dependent upon inductions. The two types of inference work together, each one tending to supplement and complete the work of the other.

This actual interdependence of induction and deduction is illustrated in the solution of all kinds of problems. For example, let us consider the matter of putting together the pieces of a picture-puzzle. The two types of inference are so closely interwoven that it is difficult to determine where one leaves off and the other begins. Both are involved in the recognition of the problem and in the preliminary steps taken toward its solution. One must, for instance, recognize the kind of problem with which he is dealing. He must know in this case that his problem is a picture-puzzle and that all picture-puzzles are solved by following certain types of procedure such as discovering particular pieces so shaped that they fit together. This part of the process is clearly enough deductive. But if we would go back still further to the way in which we first reached our definition of a picture-puzzle (and this is necessary before the particular problem could be recognized as belonging to this class), we would have an example of inductive reasoning.

Indeed it is extremely difficult to point to any one mental operation and say that it marks the real beginning of the process. Each step derives its meaning, at least in part, from the step that preceded it. With these preliminary steps completed, one begins looking for particular pieces that will fit together. This continues until enough parts are assembled to enable one to get some idea concerning the meaning of the picture as a whole. This part of the process is inductive. It is a case of drawing a general conclusion on the basis of particular facts. But as soon as one grasps the idea of the picture as a whole, he reasons again deductively. He now looks for those parts which necessarily belong to the picture he has in mind. If these parts are found his conclusion is verified and the problem is soon solved. But it may be that the first picture which he has in mind is not the correct one, and the remaining pieces cannot be assembled in accordance with that idea. He must then reason inductively again until a new conclusion concerning the picture as a whole is reached. It will then be necessary to make more deductions from this new conclusion and so on until all the parts of the picture-puzzle have been assembled.

The reasoning which we have seen involved in the putting together of the pieces of a picture-puzzle is analogous to that which takes place in any field of science. The particular facts contained in any field of knowledge correspond to the pieces of the picture-puzzle. Taken by themselves they have very little, if any, meaning. But properly assembled each one takes on a new significance and contributes to the meaning of the picture as a whole. The laws or principles by which these scientific facts are related to each other correspond to the picture taken as a whole. The purpose of any science is to discover the laws which operate within that field and to show how these laws are related to the particular facts which that science includes. And since this purpose can be realized only through the cooperative use of inductive and deductive reasoning, we can see why it is not correct to speak of certain sciences as being entirely deductive and other sciences as purely inductive. The fact is that all sciences are both inductive and deductive. This does not mean that one of these types of inference cannot be used to a greater extent than the other in some fields. Obviously this is the case in the field of mathematics where induction is used only in connection with the original definitions and postulates, and the rest of the science is a matter of deductions from these. But in the case of most of the physical sciences one type of reasoning is used about as much as the other.

Scientific Imagination. In addition to the use of inductive and deductive types of reasoning there is a third factor equally important for the development of science. It is the creative function of the imagination. By this term we mean the ability to view at once and as a whole the facts in a given situation and to interpret these in the light of some general principle or law. In other words it is the ability of the mind to form an hypothesis or a tentative explanation of the phenomena under investigation. We have said that in order to make observations that will be of some scientific value we need to have these observations guided by some principle. We must know what to look for and we must be able to distinguish between the relevant and the irrelevant facts. But this is possible only when we have some hypothesis in mind and can make our observations with reference to it. The formation of these hypotheses is the work of the imagination. The readiness and the accuracy with which these hypotheses can be formed is to a large degree a measure of one's ability as a scientist. This creative power of the imagination is most pronounced in the case of the genius but it is present to some degree in the mind of anyone who can recognize a problem and reach its solution by means of thinking.

There are some who object to the use of the term *imagination* as one of the essential factors in the work of the scientist. They regard imagination as something that is fundamentally opposed to science, and they contrast the well-established views of the scientists with the imaginings of the naïve or primitive mind. Imagination is for them another name for the world of dreams and fantasies. The objects of this world exist only in the individual mind. They have no universal or objective validity. But it is not necessary to confuse the meaning of the term with its erroneous or its non-productive use.

It is true enough that some imagination has been a hindrance rather than an aid to science. But it is not true of all imagination. And to reject imagination entirely because it has sometimes been faulty would be as foolish as it would be to reject the use of steam since some boilers have exploded. Imagination is a dominant factor in the minds of all those who think. It characterizes the mind of the great scientist or artist no less than it does that of the layman. As Karl Pearson expresses it in his *Grammar of Science*, "disciplined imagination has been at the bottom of all great scientific discoveries. All great scientists have in a certain sense been great artists; the man with no imagination may collect facts but he cannot make great discoveries."

The distinguished scientist John Tyndall in his famous lecture entitled "Scientific Use of the Imagination" says: "Bounded and conditioned by cooperant Reason, imagination becomes the mightiest instrument of the physical discoverer . . . In fact, without this power, our knowledge of nature would be a mere tabulation of co-existences and sequences. We would still believe in the succession of day and night, of summer and winter; but the soul of Force would be dislodged from our universe; causal relations would disappear, and with them that science which is now binding the parts of nature into an organic whole." And again in the same lecture he says: "There is in the human intellect a power of expansion — I might almost call it a power of creation — which is brought into play by the simple brooding upon facts."

Without this creative power of the mind Newton's observations would not have led to the law of gravitation; Faraday's experiments would not have led to discoveries in the field of electricity; Count Rumford would not have developed his new theory of heat; nor would any other of the great discoveries and achievements of science have been made.

There is something about scientific imagination that seems to defy any attempt to analyze or explain it. It is something like the interest which one may display in his work. You cannot say just what it is and yet you know very well that it makes a world of difference whether or not you have it. Sometimes it is said that the scientist has an intuitive grasp of the situation. He sees directly the probable solution of his problem. But this reference to intuition does little to aid our understanding of imagination, and unless we are careful in our use of that term, it is likely to lead to confusion.

Two things, however, do seem fairly clear with reference to the creative power of the imagination. In the first place this ability to originate hypotheses does not come about by pure chance. It is not a characteristic to be found in any type of mind but only in certain types. The statement frequently made that the great discoveries of science are the result of chance observation is likely to be misleading. The traditional story about Sir Isaac Newton watching the apple fall to the ground and his later discovery of the law of gravitation may serve as an illustration. The observation of a falling apple does seem to be a chance phenomenon. But why, it may be asked, did not other people who saw apples fall to the ground discover the law of falling bodies? The answer is clear enough. They did not have the imagination of a Newton. They could witness the same phenomenon but it would not have the same meaning for them. They could not see it in relation to other things as he could.

Count Rumford, while boring cannon in an arsenal at Munich, observed that the metallic chips which fell to the floor were hot. This observation on his part led to the discovery of the modern theory of heat. Now other people had many times before observed the same thing, yet they made no discoveries from it. The reason is that Count Rumford's mind was different from theirs. He could see, through his imagination, this particular phenomenon as a part of a larger system of things. This enabled him to grasp the significance of his observation and to construct an hypothesis that could be tested by means of experiments. This ability on his part was not a chance factor but rather the result of certain qualities of mind.

In the second place we may say that the creative power of one's imagination is conditioned by his past experiences and by his ability to recognize analogies or similarities between the new problem and other ones that have already been solved. As the range of one's experience becomes larger and his knowledge of facts is increased, he obtains more material which may serve as the basis for analogies. This explains, at least in part, the occurrence of brilliant ideas to those individuals who have been trained in the methods of science and who are familiar with a wide range of facts in the particular fields in which they are working. The medical scientist, for example, who is studying some disease for the purpose of discovering its cause will be more likely to produce a valuable hypothesis than one who is unfamiliar with the subject of diseases in general. This is due to the fact that he has a wider basis for analogies. He has more things in mind with which he can compare the disease that he is studying. For the same reason, observation of the movements of heavenly bodies will be more meaningful to the astronomer than they will to the layman; social and political events will be more meaningful for the historian, and so on for all the fields of human knowledge.

Scientific imagination is characterized by a critical attitude that is usually lacking in the imaginations of the naïve or untrained mind. The person who is unfamiliar with either the methods or the facts of a given field of science will be able to invent some kind of an hypothesis. But the explanation that in all likelihood he will put forward will be one that either goes beyond or contradictory to that which is warranted by the facts in the case. And having formed his hypothesis he is not likely to criticize it for the purpose of discovering its weaknesses. The tendency is rather for him to accept it as final and to neglect any evidence which may indicate that it is wrong. It is in this way that superstitions and all sorts of erroneous beliefs have come into existence and have been perpetuated in the minds of so many people long after they have been proven false.

The scientist, on the other hand, though his original hypothesis has been guided by his past experiences and for that reason is more likely to be correct, does not accept it as final. He tests it out by making deductions from it and by comparing these with observed facts. He searches for any facts that may be contradictory to his hypothesis, and when he finds them he revises his original conception to make it harmonize with all the facts. The scientist does not reject nor ignore any facts, but constantly revises his theories in the light of all the evidence he possesses.

Viewed from the standpoint of logic, the progress and development of the whole structure of science has been none other than the result achieved by the use of these three parts or elements of the reasoning process which we have discussed, viz., induction, scientific imagination, and deduction. These three processes have not been employed separately, but, in connection with each problem and its solution there has been an interlacing of the three. That these processes are mutually interdependent can readily be seen by making an analysis of any piece of scientific work. On the basis of what we know concerning the development of science in the past, we can safely say that in order to do successful work as a biologist, historian, economist, or indeed to become competent as an investigator in any field of knowledge one must possess a creative imagination and be able to reason correctly, both in the matter of determining the implications of universal propositions and in drawing inferences from particular facts.

Although these three processes are related to each other organically so that each one finds illustration in every great achievement of science, a glance at the history of logic will reveal the fact that at different periods they have not all received the same emphasis. During the Middle Ages, to cite one example, we find deductive reasoning occupying not only the centre but practically the entire field of logic. Practically no attention was given to the matter of induction or to anything other than the matter of showing what inferences could be drawn from certain doctrines which were recognized as authoritative. At a later time a similar emphasis was given to induction, and the other two factors were either minimized or omitted entirely. The logic of Francis Bacon and of John Stuart Mill was considered to be entirely inductive, the latter even going so far as to declare that the syllogism was not a valid instrument for the attainment of truth.

But even though emphasis has at certain times been given to deduction and at other times to induction, this should not blind us to the fact that they are both essential elements of the same reasoning process. Neither one can function independent of the other and both must be supplemented by the creative work of the imagination. The emphasis on deduction during the Middle Ages was due to the spirit of the times. It was an age dominated by the idea of authority.

So long as people started with an accepted authority and reasoned deductively from it, there was no danger of going contrary to the doctrines of the church. But inductive reasoning would likely weaken faith in the established authorities. The emphasis upon induction which we find in the writings of Francis Bacon and John Stuart Mill was due to an opposite spirit. They wanted to get away from authorities and establish only those doctrines which could be shown to have a sound basis in the facts of experience.

QUESTIONS AND EXERCISES

1. What is the difference between description and explanation? Explain the statement that all explanations are descriptions.
2. In what sense is it true that science deals only with impersonal facts? Explain the statement that science deals only with secondary causes. What is meant by a primary cause?
3. What is meant by a *verifiable* conclusion? In what sense is it true that the goal of science is prediction?
4. What is the "law of parsimony"? the "uniformity of nature"? Explain the function of each of these in scientific procedure.
5. What three types of inference were recognized by Aristotle? Why is his classification unsound? Distinguish between inductive and deductive reasoning. Illustrate each.
6. Show how inductive and deductive reasoning are mutually interdependent. Illustrate the interdependence of these two types of inference by showing how they are employed in the solution of some particular problem.
7. What is meant by the "scientific imagination"? How does it differ from the imagination of a poet? Show how scientific imagination is conditioned by a wide knowledge of facts.
8. Explain the statement that the scientist always takes a critical attitude toward his hypotheses.
9. Describe briefly the function of analogy in the formation of scientific hypotheses.
10. Show how scientific imagination, induction, and deduction are interdependent. Illustrate with reference to some particular problem.
11. Explain the emphasis that has been given to one or another of these processes at different periods in the history of thought. Which one was emphasized most during the Middle Ages? Why?

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CHAPTER III

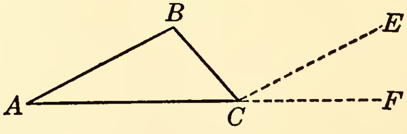
EXAMPLES OF REASONING ANALYZED

We have already noted that progress in science is made possible through the combined use of the creative imagination and the two reasoning processes which we have called induction and deduction. These three factors work together and are mutually interdependent. As a general rule we find each of them illustrated whenever we make a thorough analysis of any complete piece of reasoning. This is true regardless of the scientific field from which the example has been selected. In some fields, to be sure, the main emphasis will be placed upon one of these factors, the other two occupying a relatively subordinate place. But in these cases it is the nature of the material studied in the specific field which determines where the greater emphasis shall be placed. It is the purpose of this chapter to illustrate somewhat further the function of each one of these three factors by showing how it has been employed in the solution of specific problems. We will begin with an analysis of a simple problem in geometry which we shall use to illustrate the reasoning process as it is employed in the field of mathematics.

REASONING IN MATHEMATICS

Theorem—*The sum of the three angles of a triangle is equal to two right angles.*

The proof of this theorem may be established in the following manner:



Let ABC represent any triangle. We wish to prove that the sum of the angles A, B, and BCA is equal to two right angles.

Let us draw CE so that it will be parallel to the line AB, and extend the line AC to point F.

Now we know that the sum of the angles BCA, BCE, and ECF is equal to two right angles since the sum of all the angles about a point on the same side of a straight line passing through the point is equal to two right angles.

But we also know that angle A is equal to angle ECF since these two angles are exterior-interior angles of the parallel lines AB and CE and it can be proved that whenever two parallel lines are cut by a transversal, the exterior-interior angles are equal.

We know further that angle B is equal to angle BCE since these two angles are alternate-interior angles of the parallel lines AB and CE and we can prove that whenever two parallel lines are cut by a transversal the alternate interior angles are equal.

We have now only to substitute for the angles BCE and ECF their equals, the angles A and B, and we have proved that the sum of angles A, B, and BCA is equal to two right angles.

Here we have a typical example of reasoning in the field of mathematics. The conclusion reached is so well established that one is compelled to assent to it once he sees clearly the various steps by which it has been reached. Each stage of the argument is a logical deduction from the one which preceded it until we reach the assumptions upon which the entire argument rests. If these assumptions are true, then the rest of the argument is true and the validity of the conclusion is established beyond the possibility of doubt. This enables us to see why it is that mathematical knowledge is characterized by a degree of certainty that is not possessed by any other field. Indeed we may say that the certainty and exactness which we find in mathematics constitute an ideal toward which other sciences aim but which they are never able to realize completely. Some philosophers have tried to produce systems of thought which would explain the workings of the universe with the same degree of certainty which one finds in mathematics, but they have never succeeded in their attempts.

What now are the assumptions upon which the proof of our geometrical theorem was based? We may indicate three types. They are, first of all, *definitions*; second, *axioms*; and third, the principles of reasoning known as the *laws of thought*. Let us consider briefly each of these.

(1) *Definitions*. The above theorem, like every other one found in the text-books of geometry, involves the use of terms the meanings of which are implied in the argument. These meanings must be clearly understood before the matter of proving the theorem can be made intelligible. A straight line, for example, is defined as the shortest distance between two points. Again, parallel lines are defined as lines that do not meet no matter how far they may be extended. Likewise triangles, right-angled triangles, alternate-interior angles, exterior-interior angles, and any other terms employed either in the statement of the theorem or in its proof must be defined and these definitions must be assumed at the beginning of the demonstration. And if the question be raised concerning the origin of these definitions we can only reply that they have been obtained from former experiences or else they have been constructed arbitrarily for the purpose of fixating certain definite meanings.

(2) *Axioms*. The proof of our theorem is again dependent upon certain axioms or self-evident truths. It is assumed, for example, that magnitudes which are equal to the same magnitude, or to equal magnitudes, are equal to each other. Other axioms are: "If equals are added to equals, the sums are equal," "If equals are taken from equals the remainders are equal," "The whole is greater than its parts," "The whole is equal to the sum of all its parts," etc. These axioms or postulates are necessary assumptions without which the science of geometry would be impossible. They are not, however, derived from experience if by that we mean that they have their basis in the particular facts which pertain to the world in which we live. They are

rather constructions of the mind which have been found useful in the organization of our knowledge.

The postulates of Euclidean geometry are not the only possible ones. Non-Euclidean geometries have been invented with postulates which are contradictory to those of Euclid but which are nevertheless equally useful for the organization of knowledge. We cannot say that the postulates of any particular geometry are true and that those of other geometries are false. To do so would imply that one set of postulates conforms to the world of our experience and that the others do not. But such is not the case. Non-Euclidean geometry corresponds to the world of our experience just as well as Euclidean geometry does, and consequently the postulates of the one are as valid as those of the other. The important thing to be remembered, however, is that once a set of postulates has been put forward for a given science, they must be regarded as fixed and absolute within that particular field. The postulates of Euclidean geometry, for example, cannot be set aside or contradicted so long as we are using that kind of geometry. They are self-evident truths within that system.

(3) *The Laws of Thought.* The third assumption upon which the proof of our geometrical theorem is based may be designated by the so-called *Laws of Thought.* These laws are implied not only in the science of geometry but in all fields of human knowledge. They are in fact necessary assumptions for all thinking. They are known as the *Law of Identity*, the *Law of Contradiction*, and the *Law of Excluded Middle.* The law of identity is sometimes stated in the following manner: "A is A." It means that the essential nature of things remains constant. Not that changes never take place in the world of experience, but that in and through these changes there persists an identity. Particular pieces of iron, for example, are always changing but there is something about the nature of iron itself that does not change, and hence there are certain judgments which we can make about iron that will be universally true.

The law of contradiction is the same principle stated negatively. It means that a thing cannot be what it is and what it is not at the same time. Obviously reasoning about anything would be impossible if this principle were violated. The law of excluded middle states the same principle again in another way. According to this law contradictories do not admit a middle ground. Between A and non-A there can be no middle ground. A thing must be one or the other. In other words, the two classes are mutually exclusive and they are exhaustive.

We have now considered briefly each of the three types or classes of assumptions upon which the proof of the theorem was based. Granted these definitions, axioms, and the laws of thought, the rest of the argument is purely a matter of deduction from these. If the deductive process has been carried through without error, then the conclusion must be valid. The demonstration has shown clearly that it was really implied in the assumptions with which the argument began.

One more point should be added before we conclude our analysis of this example of reasoning. The propositions with which we have been dealing are not descriptive of the world of physical objects. In the proof of our theorem reference was made to angles and triangles. But we must not suppose that the angles and triangles or the straight lines and points and circles of geometry have any actual existence in the physical world. The straight line is by definition something that possesses no width, and points are objects that have no magnitude. But all actual straight lines do possess width and all actual points have some magnitude. Hence, all the figures of geometry, (and we may add the same statement holds true for the other branches of mathematics), have their existence only in the world of ideas. It is for this reason that the science of mathematics is capable of giving us knowledge that is exact and absolute. And it is for this reason that Bertrand Russell, himself a distinguished mathematician, has said that "mathematics is the science in which we never know what we are talking about or whether what we are saying is true."

Two plus two is exactly equal to four so long as we are dealing purely with abstract ideas. But two plus two is never exactly equal to four when we are dealing with actual physical objects. When we proved that the sum of the angles of a triangle is equal to two right angles, we did so only for ideal triangles and for ideal right angles. Thus we see that correct reasoning in the field of mathematics is not determined by a comparison of the results obtained with observed facts in the physical world. It is rather a matter of consistency with the basic assumptions upon which the science rests.

GALILEO'S EXPERIMENTAL WORK WITH FALLING BODIES

When we turn from the field of mathematics to that of the physical sciences we find that the validity of our reasoning is determined not alone by the principle of consistency with the original definitions and assumptions of the science with which we are dealing, but also by seeing whether or not our conclusions correspond to actual facts in the physical world. The physical scientist must in the earlier part of his procedure follow the same methods of reasoning as the mathematician. He begins, of necessity, with certain definitions and postulates and then determines in mathematical fashion the implications of these. This is the reason why mathematics plays so essential a rôle in the work of the physical sciences. But as soon as the physical scientist has determined the implications of his definitions and postulates he must begin his observations of nature and find out from these whether his conclusions can be verified by facts. His observations will then be guided by some definite principle which will enable him to determine which particular facts are relevant to his problem. For the purpose of illustrating the logical procedure involved in the work of the physical sciences, we will now consider one of the experiments performed by Galileo in his attempt to find the law that governs the movement of falling bodies.

Although the accelerated motion of freely falling bodies was a phenomenon that had long been observed, no attempt had been made prior to Galileo's time to state exactly the rate of acceleration or to express mathematically the relationship between the distance covered and the time of descent. The belief had persisted from ancient times that heavy bodies fall faster than light ones and all motion was usually explained in terms of some hidden purpose or some other kind of mysterious power. Galileo was not concerned with the question of what causes bodies to fall. He gave his attention rather to the matter of how they fall, or, in other words, he sought to discover the exact ratio between the space traversed and the time of descent. His definition of accelerated motion is as follows: "A motion is said to be uniformly accelerated, when starting from rest, it acquires, during equal time intervals, equal increments of speed."*

The first hypothesis which he considers seriously is that velocities increase in a manner which is directly proportional to the distance traversed. This view is put forth by Simplicio, one of the characters in Galileo's dialogue, in the following words: "I am one of those who accept the proposition, and believe that a falling body acquires force in its descent, its velocity increasing in proportion to the space, and that the momentum of the falling body is doubled when it falls from a doubled height; these propositions, it appears to me, ought to be conceded without hesitation or controversy."†

But to this statement, Salviati, another of the characters in the dialogue, replies: "And yet they are as false and impossible as that motion should be completed instantaneously; and here is a very clear demonstration of it. If the velocities are in proportion to the spaces traversed, or to be traversed, then these spaces are traversed in equal intervals of time; if, therefore, the velocity with which the falling body traverses a space of eight feet were double that with which it covered the first four feet, then the time intervals required for these passages would be equal. But for one and the same body to fall eight feet and four feet in the same time is possible only in the case of instantaneous motion; but observation shows us that the motion of a falling body occupies time, and less of it in covering a distance of four feet than of eight feet; therefore it is not true that its velocity increases in proportion to the space."

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* Galileo, "*Dialogues Concerning Two New Sciences,*" p. 162. Translated by Crew & Salvio.

† *Ibid.*, p. 167.

Having rejected this hypothesis because of the contradiction involved in it, another one is put forward as follows: "The spaces described by a body falling from rest with a uniformly accelerated motion are to each other as the squares of the time-intervals employed in traversing these distances." This statement is presented as a theorem to be proved. Sagredo, the third character in the dialogue, follows with a somewhat lengthy exposition in which he sets forth the meaning of the theorem and shows that the implications which it carries are free from contradiction. Following this exposition, Simplicio says, "In truth I find more pleasure in this simple and clear argument of Sagredo than in the author's demonstration which to me appears rather obscure; so that I am convinced that matters are as described, once having accepted the definition of uniformly accelerated motion. But as to whether this acceleration is that which one meets in nature in the case of falling bodies, I am still doubtful; and it seems to me, not only for my own sake but also for all those who think as I do, that this would be the proper moment to introduce one of those experiments—and there are many of them I understand—which illustrate in several ways the conclusion reached."

The record of the experiment which Galileo performed is then reported by Salviati as follows:

> "A piece of wooden moulding or scantling, about twelve cubits long, half a cubit wide, and three finger-breadths thick, was taken; on its edge was cut a channel a little more than one finger in breadth; having made this groove very straight, smooth and polished, and having lined it with parchment, also as smooth and polished as possible, we rolled along it a hard, smooth and very round bronze ball. Having placed this board in a sloping position, by lifting one end some one or two cubits above the other, we rolled the ball, as I was just saying, along the channel, noting in a manner presently to be described, the time with an accuracy such that the deviation between the two observations never exceeded one-tenth of a pulse-beat. Having performed this operation and having assured ourselves of its reliability, we now rolled the ball only one-quarter of the

length of the channel; and having measured the time of its descent, we found it precisely one-half of the former. Next we tried other distances, comparing the time for the whole length with that for the half, or with that for two-thirds, or three-fourths, or indeed for any fraction; in such experiments, repeated for a full hundred times, we always found that the spaces traversed were to each other as the squares of the times, and this was true for all inclinations of the plane, i.e., of the channel, along which we rolled the ball. We also observed that the times of descent, for various inclinations of the plane, bore to one another precisely that ratio which, as we shall see later, the author had predicted and demonstrated for them.

"For the measurement of time, we employed a large vessel of water placed in an elevated position; to the bottom of this vessel was soldered a pipe of small diameter giving a thin jet of water, which we collected in a small glass during the time of each descent, whether for the whole length of the channel or for a part of its length; the water thus collected was weighed, after each descent, on a very accurate balance; the differences and ratios of these weights gave us the differences and ratios of the times, and this with such accuracy that although the operation was repeated many, many times, there was no appreciable discrepancy in the results." *

Let us now analyze this experiment with reference to the three elements of the reasoning process which we have discussed, viz., imagination, induction and deduction. The *scientific imagination* is illustrated in the construction by Galileo of a definition for accelerated motion, and in his recognition of a specific problem concerning the exact ratio of this acceleration to the times during which a body is falling. It is this aspect of his work which, more than anything else, distinguishes him from the medievalists and marks his achievements as thoroughly modern in spirit. No longer concerned with the question of *why* bodies fall, he was then able to turn his attention to the problem of *how* they fall. Implied of course in his attempt to find the law of falling bodies is the conviction that such a law really exists. Should the velocity of falling bodies or the rate of their acceleration be the result of some chance factors instead of a universal principle, then it would be useless to perform experiments or to reason in any way about the matter. The existence of universal laws of nature, constant in their operation and admitting of no exceptions, is a basic assumption for all the physical sciences. But the recognition of this principle in relation to the particular motions of falling bodies was the work of Galileo's imagination.

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* From Galileo, *Dialogues Concerning Two New Sciences,* translated by Crew and Salvio, pp. 178-179. By permission of The Macmillan Company, publishers.

The second phase of Galileo's work is illustrative of deductive reasoning. The logical process involved here is essentially the same as that which we find in the field of mathematics. In fact Galileo was so impressed with the mathematical character of his work that he entitled the book in which his experiments and conclusions were first published *Discourses Concerning Mathematical Demonstration*, thus indicating the importance which he attached to this type of thinking. Throughout his writings he employs the terminology of mathematics such as *theorems*, *corollaries*, and *demonstrations*, and he gives particular emphasis to the fact that his theories were always fully worked out in his own mind before he began his actual experiments.

The assumptions on which Galileo based his deductions include his definition of accelerated motion and the principle of the uniformity of nature as well as the so-called laws of thought. Taking these for granted he reasoned at first that the distance covered by a body in motion was directly proportional to the time of descent. But when, by a further deductive process, the implications of this proposition were brought to light, he saw the contradiction which it involved. For, granting the proposition to be true, it would follow that motion must take place instantaneously or, to cite a particular case, a body would fall eight feet in exactly the same interval of time as it would fall four feet. This contradiction which the proposition implied was enough to show that the theory was false. There was no use to test it out by experiment. Deductive reasoning was sufficient to demonstrate its falsity. But having proved that his first theory was false, Galileo again reasoned deductively from his basic assumptions, and finally arrived at another theory, the implications of which were free from any logical contradiction. This proved that his theory was mathematically correct, but whether it corresponded to facts in the physical world was something that still remained to be proved.

The verification of his theory by means of experiment constituted the third phase of Galileo's work. It was in this connection that he made use of the so-called inductive methods of logic. In order that he might compare his theory with actual facts in the world of nature, he constructed his inclined plane and devised an accurate method for the measurement of short intervals of time. With these instruments at hand it was possible for him to observe and record the exact distance through which a body would fall in a given interval of time. After performing the experiment a number of times and under varying conditions, he found that the actual ratio between the time of descent and space traversed by a falling body remained constant and corresponded exactly with the formula which he had set out to test. By varying the angle at which the plane was inclined and thus causing the object to fall at different angles, he proved that the ratio which he had established held true for all angles at which a body might fall. When this experimental work had been completed, Galileo's theory was verified. He had discovered the principle which governs the accelerated motion of falling bodies and had succeeded in formulating a general or universal scientific law.

AN EXAMPLE OF REASONING IN THE FIELD OF BIOLOGY

For the purpose of illustrating further the three phases of the reasoning process and their interrelatedness in the process of discovering new truth we will next consider some of the experiments which Pasteur performed in connection with his study of hydrophobia. Prior to Pasteur's time little had been known concerning the cause of this disease or the treatment to be given for it. It was known that it was present in the saliva of the mad animals; that it was communicated through bites; and that the period of incubation during which the disease would develop varied from a few days to several months.

Pasteur's study of this disease began when there was brought to the hospital where he worked a five-year-old child who was suffering with the dread malady and who within a few hours died from it. About four hours after the child's death, Pasteur took some of the mucus that had gathered in its mouth and after mixing it with some water inoculated some rabbits. These rabbits died within thirty-six hours; and when their saliva was injected into other rabbits, these died within an equally short period of time. Some of the men who were associated with Pasteur in these experiments drew the conclusion immediately that these rabbits had died from hydrophobia. But Pasteur was not so sure about it. The fact that the animals had died within a shorter period than was usually necessary for the development of this disease led him to think that the cause of death might have been something other than hydrophobia. Further experimentation, during which he inoculated many rabbits with saliva taken directly from the jaws of a rabid dog but failed in the majority of the cases to transmit the disease, convinced him that rabic saliva was not a sure means of transmission.

Pasteur next turned his attention to that part of the nervous system known as the medulla oblongata. He thought it quite possible that the seat of the disease could be found here, since one of the characteristic symptoms of hydrophobia was to be found in the strange contortions and twistings of the muscles of the face and tongue. As a student of physiology and of neurology, he knew that the nerves which control these muscles have their nuclei in the medulla. Here, then, was a new hypothesis and Pasteur began another set of experiments to test it out. Taking the brain from a dog that had just died from hydrophobia, he carefully extracted a portion of the medulla and after mixing it with some sterilized broth inoculated the substance into the blood of several rabbits and dogs. Without exception these animals succumbed to the disease. Pasteur had now found a sure means of transmission. Further experimentation enabled him to determine the virulence of the substance used for inoculation so that he could predict with accuracy the time when any of the inoculated animals would develop the disease.

The next task which Pasteur faced was that of finding some way to build up a resistance within the animals so that they could be made refractory to the disease. He reasoned that if he could decrease the virulence of the substance used for inoculation until it was practically zero, he could then inject it into the blood of an animal without transmitting the disease. He might then be able gradually to increase the virulence and through subsequent inoculations build up a resistance that would in time give full protection to the animal. At any rate it was a theory worth trying out. Accordingly, Pasteur extracted some of the medulla from a rabbit that had just died from rabies, and after suspending it by a thread in a sterilized jar from which atmospheric dusts had been excluded, he allowed it to remain for a period of fourteen days. During this time the virulence of the medulla was gradually reduced until at the end of the period it had become wholly inactive. This substance was then crushed, mixed with water and injected under the skin of some dogs. The next day they were inoculated with a similar substance that was only thirteen days old. The following day they were again inoculated with substance twelve days old. This process continued each day with increased virulence until medulla was used the same day that it had been taken from the animal that had died. The animals that had been treated in this way were now immune to the disease. They could be bitten by rabic dogs or undergo inoculation of the most deadly virus. They were capable of resisting either one.

Shortly after Pasteur had learned how to make dogs immune to hydrophobia there was brought to him a little Alsatian boy, nine years old, who two days before had been bitten by a mad dog. The boy was suffering so badly from the bites that he was scarcely able to walk. Pasteur, after consulting with his associates, decided to treat the boy for hydrophobia hoping that it would be possible to produce an immunity to the disease. They inoculated him at once with medulla that was fourteen days old and repeated the operation each succeeding day, gradually increasing the virulence of the substance which they used. The treatment was successful. The boy was made immune to the disease and returned to his home in perfect health. (R. Vallery-Radot, *Life of Pasteur*, pp. 390-396.)

Let us now briefly analyze these experiments from the point of view of the logical processes which they illustrate. Scientific imagination, which always plays an important rôle in the discovery of new truth, is particularly characteristic of Pasteur's work. We find it displayed in his ability to form hypotheses which would later be tested out by making experiments. His previous scientific training and his familiarity with the fields of medicine and physiology were probably major factors in the development of his imaginative powers. While others were quite satisfied with generally accepted theories, he saw how these theories could be put to a test. This he did with the hypothesis concerning saliva. Again he saw a connection between the medulla oblongata and the characteristic symptoms of hydrophobia and this led to the formation of another hypothesis, viz., that inoculation with rabic medulla is a sure means of transmitting the disease. Other hypotheses having to do with the questions of degrees of virulence in the substance used for inoculation, and with methods for building up a resistance to the disease within the body of the patient, were also developed, and always in a manner that permitted testing by means of experimentation.

Closely associated with the work of forming good hypotheses and in many respects contributing toward that end, is the process of making deductions from them. It is only in this way that the implications of a theory or hypothesis can be brought to light so that one can know for sure whether or not it is true. It was by making deductions from the generally accepted theory concerning the saliva of a rabic animal that Pasteur was able to subject the theory to an experimental test. Again it was a matter of deductive reasoning based upon his general knowledge of physiology and more particularly of neurology that led to his selection of the medulla oblongata as that part of the nervous system most affected by the disease and hence most likely to furnish a sure means for transmitting it. This does not mean that particular observations of symptoms had nothing to do with the formation of this hypothesis, but rather that the data which he obtained in this way needed to be supplemented by the deductive considerations which we have mentioned. The success of Pasteur's experiments was due in large measure to the fact that he had first of all worked out in detail the implications of his hypotheses and anticipated by deductive reasoning the results that he expected to take place. This enabled him to construct experiments that would test crucial points of his theories. It also told him what to look for, thus making it possible for him to observe the facts that were relevant to the particular problems under consideration.

Pasteur's work, like that of Galileo, involved the use of definitions and basic assumptions. It was also necessary in his case to work out the implications of these by deductive reasoning. And finally the validity of his conclusions had to be determined in the same way, that is, by constructing experiments to see whether or not these conclusions corresponded with actual facts in the world of nature. It was not until Pasteur had made many inoculations with rabic saliva and observed the results in all of these cases that he was sure the disease could not always be transmitted by that means. And while his hypothesis concerning the medulla was a logical deduction from well established truths, he could not be sure of his conclusion until he had tried it out. And the same thing was true with regard to his hypotheses about making animals and human beings immune to the disease.

QUESTIONS AND EXERCISES

1. Mention two ways in which reasoning in the field of mathematics differs from reasoning in the field of the physical sciences. Why is there a higher degree of "certainty" in the field of mathematics?
2. What are the "assumptions" of reasoning in the field of mathematics? What were some of the definitions employed in the example cited? What are some of the axioms employed by the mathematician? What is the basis or ground for these axioms?
3. What are the so-called "Laws of Thought"? Under what

conditions is the law of identity violated? Give illustrations. In what sense are the axioms of geometry based upon experience, and in what sense are they not based on experience? Explain the statement of Bertrand Russell that the mathematician is one who doesn't know what he is talking about or whether what he is saying is true.

4. What is the function of deductive reasoning in the field of mathematics? How is this function illustrated in the example cited of Galileo's work?
5. What place did the scientific imagination have in his work? Describe the way in which his conclusions were verified experimentally.
6. Discuss the rôle of the scientific imagination, deduction, and verification, respectively in the case of Pasteur's work on the subject of hydrophobia.
7. Describe some experiment which you have performed and point out the way in which each one of the three phases of the reasoning process was used.
8. Analyze some problem in the field of history showing the function of each one of these three parts of the reasoning process.
9. Select an argument from your reading of the newspaper or attendance at some lecture and point out the use of induction and deduction in connection with it.
10. Read Edgar Allan Poe's essay entitled *The Gold Bug* and make an analysis of the mental processes used in the interpretation of the code that was discovered.
11. Solve the following cryptograms and make an analysis of the steps taken in the solution of each one.
    (a) hkcey eo ysiikj oajoa bkniqhwpaz.
    (b) 28 30 40 16 18 28 14 18 38 38 2 6 36 10 8
    4 42 40 40 16 10 18 28 40 10 14 36 18 40 50
    30 12 30 28 10 38 26 18 28 8.

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CHAPTER IV

TERMS AND THEIR USES

We have seen from our analysis of particular examples that the reasoning process is made up of three distinct elements. We have called these, *scientific imagination, deduction,* and *verification.* The last one includes the use of the inductive methods. We have further noted that these three elements are mutually interdependent and consequently we cannot say that any one of them exists prior to the other two. All three are actually involved in the development of even the simplest systems of knowledge, and, whenever for the purpose of analysis we separate them and study one at a time, we are dealing with artificial abstractions. But this process of abstraction is a very necessary one since we cannot give attention to all three elements at once, and we can get a clear idea of the nature and function of any one of them in no other way. Accordingly, we will begin with the scientific imagination and deal first of all with the subject of definition. It will be recalled that in our analysis of the theorem in geometry we accepted as our starting point certain basic definitions. The same was true in the case of Galileo's reasoning concerning falling bodies, and in Pasteur's work on the subject of hydrophobia. Definition then, though it does involve to some extent the processes of induction and deduction, will be for us a convenient starting-point, and for this reason we will give consideration to it first. Before doing so, however, it will be necessary to give our attention to the subject of terms since they are used in the making of definitions, and a clear understanding of definitions cannot be gained without some knowledge of their nature and function.

A logical term is any word or group of words which may be used as the subject or the predicate of a proposition. A proposition is the expression in words of a judgment or act of thought. The subject of a proposition is always an object or a class of objects about which something is stated. The predicate of a proposition is that which is affirmed or denied of the subject. A logical proposition is then composed of two terms which we may call the subject term and the predicate term and these two terms are joined by a copula which is always some form of the verb "to be," usually "is" or "are." Terms are often characterized as names. Whenever a word is used to designate some particular object or class of objects, it is employed as a name for that to which it refers.

All terms are names. As a general rule we can also say that names are terms. But there are some cases in which the latter statement is not true. A name may, for example, have several meanings any one of which may legitimately be used. But a logical term can have only one meaning. Once this meaning has been fixed, it must be retained throughout the argument. The word "partisans," for instance, may be used to refer to people whose views are narrow and prejudiced or it may be used to refer to persons who belong to a particular political party. Obviously it is the same name that is used in both cases but with meanings that are quite different. A name of this kind becomes a logical term only when some definite meaning has been attached to it. In a somewhat similar manner we may differentiate between terms and words. It often happens that terms are identical with particular words. But this is not always the case. A term may be composed not of a single word but of several of them taken together. This is true in the case of such terms as "the lamp on my desk," "the book on the lower shelf" or "the philosophy of the nineteenth century." Again it is true that any particular word may be a term if it be used as the subject or predicate of a proposition. But there are many words such as "is," "slowly," "and," "for," etc., or in other words verbs, adverbs, conjunctions, prepositions, etc., which unless they are so used cannot properly be called terms.

Singular, General, and Collective Terms. A singular or individual term may be defined as one which refers to one object and to one object only. Proper nouns as they are usually employed are singular terms. Thus "George Washington," "League of Nations" and "New York City" are all singular terms. And the same is true of the name which we give to any particular object of which there is only one. Of course there are instances in which proper nouns are used to refer to more than one object. This is the case when we use a family name such as Smith or Jones. The name is applicable to any of the members of a group. Again we may characterize a wise person as a "Socrates" or a military leader as a "Napoleon." In so doing we are using a proper name to refer to more than one object. But in these cases the proper name is no longer a singular term. Singular terms can never refer to more than one object, unless, of course, they refer to several objects considered as a unit or whole.

A general term, on the other hand, is one that can be applied to any one of a class of objects. This definition corresponds closely to that of the common noun. Such words as, "tree," "book," "flower," "window," "metal," "state university," and "trip across the ocean" are general terms. They always refer to more than one object and they may be applied either to the class of objects as a whole or to the individual members which go to make up the class.

A collective term is one that refers to a group of objects taken as a whole. It differs from a general term in that it cannot be applied to the individual members of the class, but only to the group as a whole. The term "the class in Logic," for instance, cannot be applied to each student in the class, but only to all of the students taken together. The terms "flock" and "herd" likewise refer to groups but not to particular members of the group. Other collective terms are "audience," "forest," "army," "board of directors," "House of Representatives," etc. A term that is collective in one sense may be a general term when used in another sense. For example, the term "army" is a general term in so far as it is applied to particular armies such as

"The United States Army," "The British Army," "The German Army," etc. But it is a collective term in so far as it refers to a group of units taken as a whole. Or the term "the state legislature" is collective when applied to a group of lawmakers and it is general when applied to the particular legislatures of the various states. A singular term may also be a collective term, as in the case when we use the term "the Congress of the United States." Thus we see that whether a given term is singular, general, or collective will be determined by the way in which it is used in the particular proposition.

Positive and Negative Terms. Terms may also be classified as positive and negative. A positive term is one that refers to the presence of some quality in the object to which it refers. A negative term is one that denotes the absence of some quality in the object to which it refers. Thus "white," "hot," "beautiful," "just," and "happiness" are positive terms, and "non-white," "cold," "ugly," "unjust," and "unhappy" are negative terms.

Whether a term is positive or negative in meaning is often indicated by the form of the term, negative terms being formed by adding to the positive term one of the prefixes such as "a," "anti," "un," "dis," or the suffix "less." But negative terms are not always indicated in this way. There are some terms which though positive in form are negative in meaning as is true in the case of "blind" or "cold." Again there are terms which have the negative form but are positive in meaning, as, for example, "immoral" and "unhappy." It is true that the last mentioned terms also have something of a negative meaning. One of them indicates a lack of the quality known as "moral" and the other one an absence of the quality known as "happy." In so far as the terms express this meaning they are negative terms. But they they also express another meaning. "Immoral" is not quite the same thing as "non-moral" and "unhappy" is not identical with "non-happy." There are certain positive qualities denoted by the terms "immoral" and "unhappy" and it is in this sense that they are positive terms.

Thus we see that the difference between positive and negative terms is sometimes only a matter of degree. Whether these terms are used in the sense of their positive or their negative meaning will in each case have to be determined by the propositions in which they occur. Terms such as "blind" or "maimed" are sometimes called "privative" terms, a name used to characterize those terms which refer to qualities that are normally present but from which a particular person or object has been deprived.

Contrary and Contradictory Terms. Whenever positive and negative terms are so related to each other that there is no middle ground between them they are said to be "contradictories." Thus "white" and "non-white" are contradictory terms. The same is true of such terms as "right and wrong," "true and false," "liars and non-liars." The terms used in each of these pairs are opposite in meaning, and the classification is exhaustive ; that is, there is no middle ground. Contrary terms are also opposite in meaning, but between them there is a middle ground. For example, "first and last," "white and black," "hot and cold," "wise and foolish" are all contrary terms. They denote meanings that are opposite, but because a given object is not included in one of the terms it does not follow that it is included in the other one. An object that is not first, need not on that account be last. It may be neither the one nor the other. But in the case of contradictory terms an object must belong to one or the other of the two classes. The logical contradictory of any term may always be indicated by placing "non" before the term, as in the example "white" and "non-white." Unless this designation is used there is nothing in the form of these "pairs of opposites" to indicate whether they are contraries or contradictories. When we say that contradictory terms such as white and non-white do not admit a middle ground and that any object is included in one or the other of the two terms, we mean, of course, that this relationship holds only for those things to which the idea of color is applicable. It would not be proper to speak of ideas, or religions as "white and non-white."

Absolute and Relative Terms. Terms may also be classified as "relative" and absolute" although the distinction between these two classes is more one of degree than it is of kind. An absolute term is usually defined as one which refers to an object that exists by itself. It is not dependent for its meaning upon the existence of some other object to which it is related. Such terms as "tree," "book," "the United States of America," "the course in Logic" are good examples. Relative terms refer to objects which do not have an intelligible meaning when taken by themselves. "parent," "south," "pupil," "similar," etc., are all relative terms. The object to which a relative term refers may be a particular relation or it may be an object standing in a certain relation to some other object. The term "parent," for example, is definitely related to child. It has no meaning apart from this relation. The same is true with reference to the terms "pupil" and "teacher." Neither term has any meaning apart from the other. As we have stated before, the distinction between absolute and relative terms is not an absolute one.

No term has an intelligible meaning except as it is related in some way to other objects than itself. All knowledge is systematic in character. We do not know any object until we can see it in relation to other things. Obviously from this point of view all of our so-called absolute terms are relative. And much the same thing may be said of the reverse relationship. For anything to be relative means that it is such only with reference to something that is not relative but absolute. So all of our relative terms do possess something of an absolute character. Nevertheless there is a distinction in degree. Absolute terms do have meaning when considered "relatively" independent of other terms or objects, whereas this is not true of relative terms. Relative terms often occur in pairs, as "parent and child," "buyer and seller," "ruler and subjects," etc. These terms are then called correlatives. But more than two terms may be related. One of the terms is then known as the *relate* and the others as the *correlates*.

Abstract and Concrete Terms. According to still another classification, terms are either concrete or abstract. Two meanings, however, are associated with each of these terms and it is important that we distinguish between them.

(1) In the first sense in which these words are used, a term is said to be concrete if it refers to something that can be perceived directly by the senses, and it is abstract if it refers to something which cannot be so perceived. This is the sense in which these words are usually understood. According to this definition the terms "stone," "house," "tree," "man," "book," etc., are concrete. And such terms as "justice," "truth," "beauty," "whiteness," "idea," "theory," etc., are abstract. Here again we must bear in mind the fact that the distinction is in part a matter only of degree. Common nouns do not in the strict sense of the word refer to anything that can be perceived directly by the senses. We can see a particular man but we do not see "men" in general. However the particular objects with which these common nouns are associated are perceived by the senses and for this reason we say that the general terms such as "book," "stone," or "tree" are relatively more concrete than is the case with "justice" or "truth."

(2) In the second or logical sense the words "abstract" and "concrete" have an entirely different meaning. According to this second meaning any term is abstract if it refers to something that is considered apart from the whole to which it belongs. And any term is concrete if it refers to something that is considered in relation to the system of which it is a part. From this point of view we see that the objects of our sense-perception in so far as they are considered by themselves are really abstract and it is to theories and general principles that we must turn for examples of that which is concrete. This is the meaning that is implied in the much-quoted passage from the German philosopher Hegel: "It is the uneducated person who thinks abstractly." Viewed in this way we can say that education is a process during which one's knowledge passes from the abstract to the concrete level.

Suppose, for example, that two persons are looking at a statue of Abraham Lincoln. One of them, we may imagine, knows nothing about Lincoln while the other one is thoroughly familiar with the important facts concerning his life and the part which he played in the life of his country. They would both see the same statue, but it would have very different meanings for them. One of them would be viewing it abstractly. He would see it only in isolation from other objects and events. Beyond the fact that it represented some man whom he did not know anything about, it would have no meaning for him. But the other person would view the statue concretely. He would see it in relation to a whole world of objects and events. The object of sense-perception would be for him a symbol with a wealth of meaning back of it.

The difference between the educated and uneducated person is something like this with reference to any of the fields of knowledge. The scientist will view the same objects as the untrained person but they will have larger meanings for him. He will be able to view the objects concretely. He can see them as parts of a whole system of things and thus understand the relationships which they bear to other things. But the uneducated person can grasp only their abstract meanings. He sees them apart from any larger system or whole to which they may belong.

With this second meaning in mind, we can readily see that there are a great many terms which may be used either in their abstract or in their concrete sense. Whether they belong to one class or the other can be determined only by the way in which the terms are used. But there are some terms which have no meaning at all except in their relation to a large group of things. The terms "universe," "God," "the law of gravitation," "the theory of evolution," etc., are examples of this type. Hence we are safe in saying that these terms are always concrete. But once more we must say that the distinction is one of degree. All of our human knowledge is necessarily fragmentary. We can never view anything in the light of all its relationships, and just to this extent is it true that all of our meanings are abstract. Between these two extremes, however, there is a wide difference and we may properly classify terms as abstract or concrete in accordance with the meaning which is given the greater emphasis in any particular case.

The Extension and Intension of Terms. Every term has two meanings, one of which may be called its extensive meaning and the other one its intensive meaning. These two meanings correspond in a general way to the quality and quantity of the objects to which the terms may be applied. Whenever I use the term "book" I am referring to something which possesses certain qualities or attributes, and at the same time I am referring to a certain number of objects. Likewise every other term denotes either a certain object or a group of objects and it also connotes certain qualities possessed by the object or objects to which it refers. One of these meanings is what we call the extension of the term, and the other meaning is known as its intension. By the extension of a term, then, we mean that use of the term which points out the particular objects to which the term may be applied. Thus the extension of the term "tree" is every object that can be called a tree. This may be indicated by saying "pine tree," "maple tree," "spruce," "fir," etc. The extension of the term "university" includes all of the institutions to which the name may be applied, for example, "Harvard," "Yale," "Princeton," "University of Chicago," etc. The extension of "triangle" includes all triangles and may be indicated as follows: "acute triangle," "obtuse triangle," "right-angled triangle," "isosceles triangle," etc.

By the intension of a term we mean that use of the term which describes the qualities or attributes of the object or objects to which the term refers. In general use the intension of a term is identical with its dictionary definition. Thus the intension of the term "planet" is "a heavenly body that revolves around the sun." The intension of "triangle" is "a geometrical figure that is bounded by three straight lines." And again, the intension of "river" is "a body of water that generally flows toward the sea."

As we have stated before, extension and intension are two different meanings both of which belong to every term. Usually, however, it is one or the other of these meanings that is given the greater emphasis in any specific case. There are some cases in which the extension of a term is very limited, and there are others in which the intension has been reduced to a minimum. Singular terms such as proper nouns have a very narrow extension. Since a term of this kind can refer to but one object, its extension will necessarily be limited to that particular object. For example, the term "Christopher Columbus" is limited to one certain individual who happened to bear that name. In the case of proper names which do not refer to any one person in particular but which are used to represent anyone in a general way, as, for instance, the name "John Doe," the intension of the term is considerably limited. It includes not the qualities or attributes of any one individual but only those qualities that are possessed by people in general. Terms like "ghost," "fairy," "the devil," etc., which do not refer to any object in the physical world but do nevertheless represent certain definite ideas in people's minds, are limited in their extension to the particular ideas for which they stand. The same is true of terms which denote qualities only, such as "whiteness," "justice," and "truthfulness."

It has sometimes been said that the extension and intension of terms stand in inverse ratio to each other. That this relationship usually holds true can easily be seen by increasing the intension of any term. Take, for example, the term "tree." Its extension includes all the trees in the world, and its intension is of course limited to those characteristics which are common to all trees. Suppose now that we increase the intension of the term by adding the word "pine." Our term will then be "pine tree." But by increasing the intension of the term we have thereby decreased its extension. For the number of objects to which the term "pine tree" can be applied is certainly much smaller than the number of objects that can be called "tree." If we increase the intension still further by making our term "tall pine tree" we will have decreased still more the number of objects to which it can be applied.

In general it is true that the smaller the number of qualities or attributes of a given term the greater will be the number of objects referred to by the term. And, consequently, any decrease in the extension of the term will be accompanied by a corresponding increase in the intension. But to define the relationship between the extension and intension of terms as an inverse ratio implies an exact mathematical correspondence of the one to the other which usually does not exist. If we increase the intension of the term "man" by adding the qualities "black" and "tall" we will in each case decrease the extension of the term, but we do not necessarily decrease it in the same proportion when we add "tall" as when we add "black." Nor would the extension be decreased in exactly the same amount when we add "black" as it would if we added "white." Yet these exact proportions would have to obtain if the relationship between these two meanings could always be expressed as an inverse ratio. Hence we may say that as a general rule the greater the intension of a term the smaller will be its extension and vice versa, but this is not equivalent to any definite mathematical ratio which is held to be the same for all instances.

QUESTIONS AND EXERCISES

1. Show how definition is related to the three factors in the reasoning process, viz., scientific imagination, deduction, and induction. Why is it necessary to discuss terms before dealing with definition?
2. What is a logical term? Distinguish between terms, words, and names. Define and illustrate a singular term, a general term, and a collective term.
3. Make a list of terms that may be either general or collective, depending of course on the way in which they are used. Do the same for singular and general terms.
4. Define and illustrate positive and negative terms. What is the usual form for negative terms? Give examples. Mention some terms that are negative in form but positive in meaning and vice versa.
5. Distinguish between contrary and contradictory terms. Give examples of each.

6. Mention two meanings of the words "abstract" and "concrete" and explain fully the difference between them. Explain fully the statement attributed to Hegel that "it is only the uneducated person who thinks abstractly."
7. What is meant by the extension of terms? by the intension of terms? Why does every term have both extension and intension? Criticize the statement that extension and intension stand in inverse ratio to each other, showing what truth it contains and wherein the statement is false.
8. Make a list of ten terms and write out the intension of each one.
9. Write out the extension of each of the above terms. (The extension of a term may be indicated by giving two or three examples and writing the abbreviation for "and so forth." Thus the extension of university is "Harvard university, Yale university, Johns Hopkins university, etc.")
10. Discuss the practical value of a knowledge of the various kinds of terms.
11. Write a list of ten terms, and state the contradictory of each one.
12. Write a list of contrary terms.
13. Using the meaning of abstract and concrete that was mentioned first, write a list of words to illustrate each of these two kinds of terms.
14. Illustrate the second use of abstract and concrete.

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CHAPTER V

LOGICAL DEFINITION AND DIVISION

THE purpose of definition is to fixate with clearness and accuracy the meaning of terms. Since reasoning of any kind involves the use of terms, it is quite obvious that until these terms have been given definite meanings nothing can be gained in the way of knowledge from their use. Definition is an essential part of scientific procedure. In the examples of reasoning which we examined in Chapter III, we saw that certain definitions were included in the assumptions upon which each argument or investigation was based. From one point of view, at least, we may say that all scientific work begins with definition.

It is true that the definitions with which any particular science begins are often of a provisional or temporary character and it is not until the science is well developed that final or complete definitions can be given. Nevertheless it is always true that definitions of some kind are necessary as a starting-point. It is from these that deductions are made and the nature of specific problems is determined. Obviously the success which attends the work of the scientist in any field is dependent in large measure upon the clearness and accuracy with which he formulates and uses his definitions.

Logical definition is one of the most effective means of avoiding ambiguity in one's own thoughts as well as in the statements which he makes. Many of our words have a variety of meanings any one of which may properly be used, and unless the author of an argument is careful to state the sense in which he has employed one of these words, confusion will likely be the result. One of the most common fallacies of deductive argument consists in the use of a term which has two meanings, one of which is employed in one part of the argument and the other meaning used in another part. Discussions of various topics often drift from the main point and include a great deal of material that is wholly irrelevant because the particular terms under consideration have not been defined with precision. Unless this is done there is no way of determining just what facts should be included. Discussions about religion, for example, are often profitless for the reason that no clear-cut idea has been given as to just what it is that is being discussed. Much of the confusion that often exists concerning the relationship of science and religion or of reason and faith would be avoided by first making clear the exact sense in which each term is used.

It has sometimes been maintained that all debate concerning any issue would cease if the individuals taking part would only define their terms. This, of course, is not true. It is possible for people to have a difference of opinion when the issue between them has been clearly defined and each one knows exactly what the other one means by the particular terms which he employs. Nevertheless it is true that precise definition does help more than anything else to clarify an issue. It not only enables a person to understand better what another one means but it is a most effective aid toward clearness in his own thinking. To have fixed and definite meanings associated with the words which we use is one of the most essential characteristics of good thinking.

The importance of logical definition as a remedy for confused and vague ideas has seldom been stated better than by the English philosopher John Locke, who in one of his most famous essays declared that the vagueness and confusion with which people so often use words led him to doubt seriously whether language had been an aid rather than a hindrance in the acquisition of knowledge. Certainly language has been the most valuable of all our instruments for obtaining knowledge, but the degree to which it is still able to fulfill this function is conditioned by the definite and precise use which we make of it.

Since, as we noted in our last chapter, every term has an extensive and an intensive meaning, definitions are of two kinds which correspond respectively to these two meanings of terms. We may fixate the meaning of a term by indicating the object or objects to which it refers and by showing how these are to be distinguished from other objects and classes of objects. When we have done this we have given the extensive definition of the term. This is the same thing as classifying the objects referred to in the term that we have defined. Extensive definition is then identical with classification or logical division. The intensive definition fixates the meaning of terms in another way. This type of definition states the qualities or attributes of the thing that is being defined. This is the more usual type of definition and as a general rule it is this meaning rather than the extensive meaning that is indicated by the term definition. To avoid confusion in this matter we will use the term definition only when referring to the intensive meaning of terms, and we will use "classification" or division to indicate the extensive meaning.

Kinds of Definition. Definitions have sometimes been classified as "verbal" and "real." The purpose of a verbal definition is to state the sense in which a particular word or term is employed. It gives the meaning of the word rather than a description of the object to which the word refers. For example, we may define "ferocious" as "possessing a fierce and savage nature." Real definitions, on the other hand, tell us something about the object which the term represents. When we define "iron" as "the most useful of metals" the purpose of the definition is not so much to tell us what the word "iron" means as it is to tell something about the particular metal which that word designates.

This distinction between verbal and real definitions is not however an absolute one and we must be careful not to press it too far. All verbal definitions are to some extent real and all real definitions are in one sense verbal. The reason for this is that words are always used with reference to objects. Neither one can be considered apart from the other. Hence it is true that whenever we give a meaning to any particular word we necessarily characterize to some degree the object to which that word refers. Nevertheless, the distinction is a valuable one since it often happens that the immediate purpose of a definition is to explain the meaning of a word and for this reason the verbal character of the definition is given the greater emphasis.

The *genetic* type of definition fixates the meaning of a term by giving an account of the origin of the object to which it refers. Thus water may be defined as the "substance which results from a mixture of two parts of hydrogen and one part of oxygen." Typhoid fever may be defined genetically by stating the way in which the disease develops or by describing the particular way in which it is transmitted. Or a geometrical figure may be defined in terms of the way in which it is constructed. Whether this type of definition is to be employed in preference to any other is something that is determined not only by the object to be defined but also by the particular purpose which the definition is to serve. There are some terms which for one purpose would best be defined genetically, but for other purposes another type of definition would be more suitable.

The *Aristotelian* type of definition states the meaning of a term by giving the "genus," "species," and "differentia." A "genus" is a class name. A "species" is one of the smaller units included in a class of objects. The "differentia" is made up of those unique characteristics which distinguish a given species from all other species belonging to that class. For example, in the definition "man is a rational animal," "man" is the species to be defined, "animal" is the genus or class to which he belongs, and "rational" is the differentia which distinguishes him from all other species included in the class of animals. In the definition "gold is the most precious of metals," "gold" is the species, "metals" is the genus, and "most precious" is the differentia. Genus and species are of course relative terms. A word which is used as a species in one connection may be a genus with reference to something else. The word "metal" is a genus with reference to the species "gold," "silver," "iron," etc., but it is a species with reference to the higher genus "substance."

The process known as dialectic was used by Socrates as a method for arriving at logical definitions. Dialectic is a term which refers to the question and answer method of investigation. It was used by Socrates in his discussions with the Greek Sophists as a means of discovering the essential nature of certain ethical terms such as "temperance," "courage" or "justice." He would begin by asking one of the Sophists to define the particular virtue that was being considered. Socrates would then proceed to point out certain cases which would contradict the definition that had been given. A new definition would then be proposed which would include those contradictory cases, and this would in turn be subjected to the same kind of a test as was given to the first one. This process would continue until finally a definition would be reached that would include all cases of the virtue that was being defined. Before a term could be properly defined it was necessary, Socrates believed, to discover the essential attributes of the term. Or, in other words, one must find just what it is that is common to all the cases included by the term and without which any species could not be said to belong to that class. It was with this type of definition in view that Aristotle formulated his principles of logical definition. His indebtedness to his predecessor in this field is indicated by his statement that Socrates gave to the world two things, one of which was the method of inductive reasoning and the other the art of logical definition.

There are some terms which cannot be defined by giving the genus and differentia. Obviously this is true of any term that is a "summum genus" or an "infima species." A term that represents a highest class cannot be defined with reference to a class that is still higher. Nor can the lowest or last species be used as a genus. Such terms as "life," "God," "universe," "being," etc., cannot be considered as species belonging to some more inclusive genus. Consequently if these terms are to be defined at all it must be with reference to something else. Just what the reference shall be in a given case is something that must be determined by the purpose for which the definition is given. A definition of "life," for example, that would be suitable for a biologist would not necessarily be a satisfactory one for a moralist. Each one of these persons would require a definition that was made with reference to materials belonging to his respective field. Individual or singular terms can be defined only by giving their extensive meaning.

Rules for Logical Definition. While it is true that there are some cases in which the type of definition that is most useful depends to a large degree upon the circumstances present and the particular purpose that it is to serve, there are five rules which constitute in a general way the requirements for logical definition. They are as follows:

(1) *A logical definition must state the essential attributes of the thing to be defined.* By an "essential attribute" is meant something that necessarily belongs to every member of the class that is being defined. This requirement is usually met by stating the genus and the differentia. As a general rule it is the proximate or nearest genus that is given. Take, for example, the definition "Logic is the science of correct thinking." The genus that is used in this case is "science" and in so far as the meaning of that term is clearly understood the definition is adequate. A more comprehensive definition would include not only the meaning of "logic" but that of "science" as well. This would be done by using a more remote genus which would be inclusive of science. It is always possible to use a remote instead of the proximate genus in a definition. This type of definition has sometimes been called the "comprehensive definition" to distinguish it from the Aristotelian type in which the genus that stands nearest the term to be defined is used. Another way of distinguishing between these two types is to say that the comprehensive definition states all of the essential attributes while the Aristotelian type usually gives only one. The particular attribute which is selected for the definition is determined by the purpose for which it is to be used. Thus a definition of "salt" which would be appropriate for a

chemist, would have no meaning for one who had no acquaintance with the field of chemistry.

(2) *A logical definition must be exactly equivalent to the class to be defined.* This means that the differentia must be neither too broad nor too narrow. It is too broad if it includes not only the objects that belong to the class that is being defined but other ones as well. Thus the definition, "A horse is an animal that walks on four legs," is too broad since the differentia includes more animals than horses. "Automobiles are instruments used for transportation," and "Tin is a metal that weighs less than gold" are likewise definitions that are too broad. A definition is too narrow when the differentia fails to include all of the objects to which the term that is being defined refers. If, for example, we should define "tree" so as to include only those that bear fruit our definition would be too narrow. The same would be true of the definition "A criminal is one who steals the property of another person."

(3) *A logical definition must not be circular.* A circular definition is one that uses the term to be defined or a word that is synonymous with it or derived directly from it. Thus "Definition is a process of defining terms" is clearly a violation of this rule. "A star is a stellar body appearing in the heavens," and "Energy is the force which sets things in motion" are likewise circular definitions.

(4) *A logical definition should whenever possible be affirmative rather than negative.* It is always better for the purpose of definition to state what a thing is instead of what it is not. Usually there are so many things that an object is not, that it would be almost an endless procedure to enumerate all of them. This rule is closely related to our first one. If a definition must state the essential attributes of the thing to be defined, this can hardly be done by enumerating the things that it is not. There are, however, some cases in which the immediate purpose of the definition can be met by a negative statement. This is particularly true of negative terms. But even here the definition serves more as a means of identifying the object than it does to describe its qualities or attributes.

(5) *A logical definition must not be expressed in obscure, hazy, or figurative language.* It should always be expressed in terms which the reader or hearer will clearly understand. The main purpose of logical definition is that of avoiding confusion and ambiguity in our use of words. This cannot be accomplished if the words used in a definition are less intelligible than the term which is being defined. Language which is highly figurative usually leaves one very much in doubt concerning the meaning that was intended. The use of ambiguous language is bound to have the same result. A technical terminology should be avoided when one is dealing with the general public unless care has been taken first to make clear the exact meaning of the technical terms employed. Definitions which may be unintelligible for the general public may be useful and proper for a group of scientists who are familiar with the terms used.

Logical Division—Principles of Classification. Just as logical definition has to do with the intensive meanings of terms, so logical division is concerned with their extensive meanings. Since every term has an extensive and an intensive meaning and these two are related in a definite way, it follows that we cannot know either of these meanings without knowing something about the other. And the same thing is true of logical definition and division. Each one to some extent implies the other. The goal of science includes not only the definition of terms but also their proper classification. Scientific knowledge always includes two things. It takes into account the common qualities of objects, and it also considers the differences by which these objects are distinguished from each other. Without either of these factors science would be impossible. Logical definition is an attempt to state the former of these, and logical division is an attempt to express the latter. These two processes are complementary. Both are essential for the development of science, and it is impossible to make very much progress in either one without some help from the other.

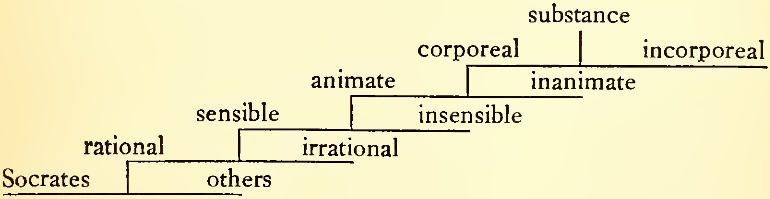
A distinction is sometimes made between logical division and classification. The basis for this distinction is found in the fact that they represent opposite ends of a single process. Division starts with the term that has the widest extension and the smallest number of qualities or attributes and proceeds through a series of species, sub-classes, and sub-species until the lowest class or "infima species" is reached. This lowest class, or as is usually the case, the individual units with which the process ends will have the greatest intension and the smallest possible extension. Classification begins at the other end. It starts with a group of individual units or objects and arranges them in accordance with their common qualities until finally the most general class or "summum genus" is reached. In other words, classification is essentially inductive in character, and division is deductive. But this distinction between division and classification, though a valid one, is only descriptive of the two complementary elements that are involved in the one process of making clear the extensive meaning of terms. It has no particular value for us when we are dealing with the process as a whole, and consequently we shall use the two terms interchangeably.

In our discussion of definition we spoke of "real" and "verbal" definitions. In much the same way we may speak of divisions as "artificial" and "natural." An artificial division is one that is based upon factors which are relatively unimportant. It would be possible, for example, for one to classify all the books in a university library on the basis of the color of their bindings. Or they might be classified according to their size or their weight. But these divisions would be artificial. The purpose which these books are designed to serve is one that is not determined by their size, weight or color. These characteristics, though they are essential to all books, are relatively unimportant and hence a classification that is based on any one of them is artificial.

Natural divisions are, on the other hand, based on the characteristic which is most important in the light of the purpose which the classification is to serve. When we classify books on the basis of the subject matter of their contents we are using this type of division. The classification of animals which one finds in an up-to-date text book of Zoology is another illustration. And the same is true of the classification of the various fields of human knowledge which one finds in a book of science. Artificial divisions are not as a general rule of very much use. Occasionally an exception arises as is the case when a physician diagnoses a disease on the basis of the symptoms which he has observed.

Kinds of Division. There are two kinds of division which need to be considered. One of these is known as "dichotomy" and the other one is usually designated as "classification." We will consider them in the order named.

(1) *Dichotomy.* The word *dichotomy* means literally *cut in two.* As a principle of division it means the separation of a given genus into two classes which are contradictory. Thus the classification of books as "histories and non-histories"; of metals as "gold and non-gold"; or of people as "Americans and non-Americans" illustrate this principle. If this method of division be carried on far enough, it will be possible to classify everything in the universe as belonging to one or the other of some pair of contradictory terms. This method is used in some parts of the Platonic dialogues and it was widely used by the medieval logicians. One of the best illustrations of its use is found in the famous "Tree of Porphyry." This was a device used by a neo-Platonist philosopher in a manner similar to the following:



This kind of division has the advantage of always being made up of classes which do not overlap, and which include all of the objects that are being divided. But it also possesses some very obvious disadvantages. To refer to any particular object as "non-everything-else-in-the-universe" does not help anyone to understand the nature of the object. It is a type of division that is based more upon what is not known concerning objects than upon what is known. And it does not distinguish between the coordinate and the subordinate species belonging to any particular class. Silver is included in the class of objects known as "non-gold," but so are many other kinds of metal. And there is nothing in a dichotomous division to show how the various classes, once they have been separated, are related to each other. Then, too, this kind of division tends toward a forcing of objects into contradictory classes when as a matter of fact the objects in question do not belong entirely to the one group or to the other. An example of this may be seen in the classification of voters as "Democrats and non-Democrats." A great many people participate in popular elections who do not belong wholly to either one of these classes.

Rules for Logical Division or Classification. In contrast with the principle of dichotomy, logical division aims at an arrangement of the various classes and sub-classes that is in harmony with the essential nature of the class of objects that is being divided. The rules which govern this kind of division are as follows:

(1) *Every logical division must be based on the essential nature of the whole to be divided.* The reasons for this are so obvious that the rule has often been considered superfluous. Naturally a group of objects cannot be classified on the basis of something which part of them do not possess. Nevertheless violations of this principle do frequently occur. For example, theories may be classified as "true and false," when as a matter of fact, theories are something about which we do not know whether they are true or false.

(2) *Every logical division must have a single basis of division.* People may be classified according to the color of their skin as "white," "black," "red," etc., or they may be classified according to the part of the world in which they live as "Americans," "Europeans," "Africans," etc. But it would not be right to classify them as "white," "Europeans," "Americans," etc. Soldiers may be classified on the basis

of having been drafted, or having enlisted; or they may be classified according to the rank which they hold. But whichever basis is used one must hold to it throughout the classification. To classify students as "poor," "good," "freshmen," and "sophomores," etc., is a clear violation of this rule.

(3) *The species into which a class is divided must not overlap.* If we classify politicians as "liberal," "conservative," "Republican," "Socialist," etc., this rule will be violated, for it is possible for an individual to be both liberal and Republican or conservative and Republican at the same time. In a logical division the species must be exclusive. The violation of the second rule will almost always result in a violation of this one as well. But it is possible to violate the third rule without changing the basis of the division.

(4) *The division must be exhaustive.* This means that the species enumerated in the division must include all of the objects in the class to be divided. In other words the constituent species must, when added together, be equal to the genus.

QUESTIONS AND EXERCISES

1. What is the purpose of logical definition? Would all disputes be settled if the parties concerned would accurately define their terms? Give reasons for your answer. Distinguish between the extensive and the intensive type of definition.
2. What is the difference between a verbal and a real definition? Give examples of each. Is the distinction between these two kinds of terms an absolute one? Give reasons for your answer.
3. What is a genetic definition? Write a genetic definition for each of the following terms: circle, smoke, average, triangle, water.
4. What is meant by the Aristotelian type of definition? How does it differ from the comprehensive type? Explain what is meant by each of the following: species, genus, differentia, summum genus, infima species. Illustrate each.
5. Describe the process known as dialectic. Tell how it was employed by Socrates in his attempts to arrive at logical definitions. To what extent was his method inductive?
6. Memorize the five rules for logical definition.

7. Illustrate with at least two examples, the violation of the first rule for logical definition.
8. Do the same for each of the other four rules.
9. What is the distinction between logical division and logical classification? Why are these terms used interchangeably in this book?
10. Explain and illustrate dichotomy as a method of division. What are the chief weaknesses of this method?
11. Explain and illustrate each of the four rules for logical division.
12. Give examples to illustrate the violation of each of these four rules.
13. Visit a school or city library and explain in some detail the way in which the books are classified.
14. From the general information which you possess concerning the various fields of knowledge, make a classification of the sciences.
15. Compare the classification which you have made with one that is printed in some textbook of general science.
16. Make a list of definitions which you have found in your general reading. Criticize each one in the light of the rules given in this chapter.
17. Make a list of terms which are frequently used in an ambiguous manner.

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PART TWO
DEDUCTIVE REASONING

CHAPTER VI

PROPOSITIONS

The Nature of Propositions. A logical proposition is anything that may be said to be true or false. It is the expression in words of an act of thought which we call a judgment. Judgments are involved in every kind of intellectual activity. They are the result of a process of comparing and evaluating particular facts of experience. The term "judgment" is frequently used in connection with the decision rendered by a court. These decisions are the conclusions that have been reached after a careful examination of the facts on both sides of a given case and after an attempt has been made to weigh or to evaluate correctly the evidence that has been presented. Something like this takes place whenever we judge that a thing exists or that it stands in a certain relation to something else. Judgments are, in this sense at least, the simplest elements of the thinking process. It is by combining them and comparing them in various ways that one's field of knowledge is increased or that the content of any science is developed.

Judgments and propositions are, as we have seen, closely related. The two terms are frequently used interchangeably. But there is a distinction between them which should be made clear. The term "judgment" refers to the psychological activity by which one becomes aware of objects and relations. It is only when one of these has been expressed in words that we have a logical proposition. Both judgments and propositions do however refer to something that exists independent of the individual who is making the judgment. It is for this reason that we can speak of certain conclusions as being forced upon us, or we can say that the logic of the situation compels us to think in a certain way.

A distinction should also be made between propositions and sentences. A proposition is necessarily a sentence. But not all sentences are logical propositions. It is only when a sentence expresses something that is affirmed or denied of an object or class of objects that it is a proposition. Wishes, commands, entreaties, prayers, questions, and exclamations are all sentences, but they are not propositions. Perhaps we may best indicate the difference between them by saying that sentences have to do with grammar, while logic is concerned with propositions. A grammatical sentence is made up of a subject and predicate, but a proposition is composed of terms, relations, and qualifying words. Propositions have to do with concrete facts but they are not identical with facts or objects of experience. A proposition is always an assertion or a denial concerning some object or class of objects.

Propositions are composed of three elements. These are *terms, relations,* and *qualifying words* which indicate the affirmative or negative character of the proposition and whether the subject term includes the entire class or only a part of it. Every logical proposition includes two terms, one of which is called the subject term and the other one the predicate term. The subject term is the object or group of objects about which something is affirmed or denied. The predicate term is also an object or class of objects that stands in some relation to the subject term. These two terms are connected by certain words which express the relation that exists between them. Traditional logic always expresses this relation by some form of the verb *to be,* usually by *is* or *are* and in certain cases by the use of *is not* or *are not.* Whichever one is used, it is known as the *copula* and it serves to connect the two terms of the proposition. The copula always expresses the relation of inclusion or exclusion. It indicates that the subject term is included in the predicate term or else is excluded from it.

But propositions may express other relations than that of exclusion or inclusion. They may, for example, express the relation of *greater than* or of *less than.* They may express the relation *east of, father of, brother of,* or any one of numerous other relations. Propositions which express one of these relations can be restated so that the relation expressed will be either inclusion or exclusion, but in so doing one necessarily omits a part of the meaning which the original proposition was intended to convey. However, for one who is beginning to work with logical propositions it is usually advisable to start with those that express the relation of inclusion or exclusion and to reduce all others to that particular form.

After one becomes familiar with the use of propositions expressing this relation, he can easily advance to those that have to do with other relations. The qualifying words which constitute the third element in propositions are *all*, *no*, and *some*. One of these words is always placed before the subject term in a logical proposition. Its purpose is to indicate whether this term is used in its widest extension and also in the case of universal propositions to indicate whether the predicate term includes or excludes the subject term.

Kinds of Propositions. Propositions may be classified according to their form as *categorical* and *conditional.* A categorical proposition is one that directly asserts or denies something of an object or class of objects. As a general rule, the subject term in a categorical proposition is said to be included in or excluded from the class of objects denoted by the predicate term. Thus "All tables are articles of furniture," "No men are immortal," "Some metals are useful," and "Some men are not liars" are all categorical propositions.

Conditional propositions also express affirmations and denials, but these are not made directly concerning any particular objects. They express rather the consequences that will follow whenever certain conditions have been fulfilled. Conditional propositions are further divided into two classes known as *hypothetical* and *disjunctive.*

Hypothetical propositions are made up of two parts, the first of which is called the *antecedent* and the second the *consequent.* The antecedent begins with the word "if" or its equivalent and expresses some condition. The consequent is that which is asserted or denied concerning the condition expressed in the antecedent. Thus "If the price of farm products be raised, the country will be prosperous," "If one works hard, he will succeed," and "If this is a metal, it is an element," are all hypothetical propositions. A disjunctive proposition is one that employs the words "either" and "or." Thus "Either the man is ignorant, or he is trying to deceive others" is a disjunctive proposition. The two conditions which are expressed in the proposition are known as *alternatives*. Either one or the other must be accepted. No third possibility can be admitted.

The Quality and Quantity of Categorical Propositions. Categorical propositions are classified according to their quality as *affirmative* and *negative*. They are classified according to quantity as *universal* and *particular*. Since every categorical proposition has both quality and quantity, there are four classes into which they may be divided. They are (1) universal affirmative, (2) universal negative, (3) particular affirmative, and (4) particular negative.

Any proposition is said to be affirmative when the class denoted by the subject term is included in the class denoted by the predicate term. For example, the proposition "All metals are elements" is affirmative since the subject term "metals" is included in the predicate term "elements." The same is true of the proposition "Some books are extremely valuable" for that part of the class "books" to which the subject term refers is included in the class of "extremely valuable things." A negative proposition is one in which the class denoted by the subject term is excluded from the class denoted by the predicate term. Thus "No aliens are citizens of this country" is a negative proposition. The subject term "aliens" refers to something that is outside of, or excluded from, the class known as "citizens of this country." And again the proposition "Some things that glitter are not gold" is a negative proposition since that part of the class of "things that glitter" to which the subject term refers is outside the class denoted by the predicate term "gold."

A universal proposition is one in which the subject term is taken in its widest extent. In other words the predicate term is affirmed or denied of the entire class denoted by the subject term. Thus the propositions "All voters are taxpayers" and "No metals are compounds" are both universal propositions. The subject term in each case includes the entire class of objects to which it refers. Particular propositions are those in which the subject term is not taken in its widest extent. It refers to only a part of the class of objects denoted by it. The propositions "Some metals are useful," and "Some men are not witty" are particular.

These four kinds of propositions are symbolized by the letters A, E, I, and O. The letters A and I are the first two vowels in the Latin word *affirmo* and they are used to symbolize the two affirmative propositions, A standing for universal affirmative, and I standing for particular affirmative propositions. The letters E and O are the first two vowels in the word *nego* and they symbolize the two negative propositions, E being used to represent universal negative and O to represent particular negative propositions.

The quality and quantity of categorical propositions is further indicated by the use of the words "all," "no" or "some" in connection with the subject term. "All" is placed before the subject term when the proposition is universal and affirmative. "No" is placed before the subject term when the proposition is universal and negative. When the proposition is particular and negative the word "not" is included in the copula. Summarizing, we may say that all categorical propositions expressing the relation of exclusion or inclusion may be put in one of the four following forms:

(1) *Universal Affirmative*
All (subject term) is (predicate term) A.
(2) *Universal Negative*
No (subject term) is (predicate term) E.
(3) *Particular Affirmative*
Some (subject term) is (predicate term) I.
(4) *Particular Negative*
(Some (subject term) is not (predicate term) O.

Putting Propositions into Strict Logical Form. Most of the propositions that have been used for illustration in the preceding sections of this chapter can easily be stated in one of the four forms given above. But there are many propositions which do not fall so readily into one of these classes, and it is often necessary to change the wording and to restate the whole proposition so that its character will be apparent. For example the proposition "Suspicion ever haunts the guilty mind" is universal and affirmative but in order to bring these characteristics to light it is necessary to restate the proposition in the following maner : "All (guilty minds) are (those haunted by suspicion) A." And "All is not gold that glitters" must be stated : "Some (things that glitter) are not (gold) O" in order to make clear that the proposition is particular and negative. This process of changing and restating a proposition so that it falls into one of these four classes is what is meant by putting propositions into their strict logical form. The reason for this procedure is that by so doing it is possible to fixate definitely the meaning of the proposition. Until this has been done it is impossible to determine just what inferences can legitimately be drawn from it. Since this form pertains only to categorical propositions which express the relation of exclusion or inclusion, any other kind of proposition must be reduced to this type before it can be stated in strict logical form.

To put propositions in logical form one should observe the following rules :

(1) Determine the subject term and enclose it in parentheses. The subject term is always the object or class of objects about which something is affirmed or denied. By putting parentheses around the term it is easier to regard the term as representing a class of objects, and one is less likely to confuse the term with words which are similar in meaning.

(2) Determine the predicate term and enclose it in parentheses. The predicate term is also an object or class of objects which either includes or excludes the objects denoted by the subject term. The use of parentheses around this term will again help to avoid confusion.

(3) Place in front of the subject term but outside the parentheses the word *all*, *no*, or *some*. If the proposition is universal and affirmative the word *all* should be used. If

it is universal and negative the word *no* should be used. Particular propositions employ the word "some" both when the proposition is affirmative and when it is negative.

(4) Place the copula between the two terms. The copula is always *is* or *are* except in the "O" proposition where it is *is not* or *are not.*

(5) Place the proper letter A, E, I, or O after the predicate term.

Propositions which have a singular term as their subject should be treated as universal since it is the entire term about which something is affirmed or denied. This type of universal proposition is sometimes differentiated from others by writing the word *individual* or its abbreviation after the letter which symbolizes the quality and quantity of the proposition. Thus the proposition "Socrates was the wisest man in Athens" if written in logical form would appear as follows: "All (Socrates) is (one who was the wisest man in Athens) A ind."

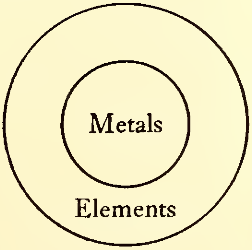
Propositions which begin with the word "few" are particular and negative. For example "Few members of the class understand the lesson" means that some of the members of the class are not ones who understand the lesson. This meaning is expressed by putting the proposition in its logical form, as "Some (members of the class) are not (those who understand the lesson) O." This does not necessarily imply that some of the members of the class are those that do understand the lesson. This latter proposition may be either true or false but in either case it is not included in the meaning of the original proposition. When a proposition contains the expression "a few" the meaning will be affirmative and the proposition should be classified as an I. For example, "A few states went Republican in the last election" takes the following logical form: "Some (states) are (those that went Republican in the last election) I."

Whenever the word "all" occurs at the beginning of a proposition it must be determined whether the word is used in its distributive or its collective sense before the proposition can be put into logical form. In the proposition "All the angles of a triangle are equal to two right angles," the word "all" is used in its collective sense. It refers to all of the angles taken together. But in the proposition "All the angles of a triangle are less than two right angles" the word is used in its distributive sense; that is, it refers to each of the angles taken separately. Whether the word is used in one sense or in the other can be determined only by the meaning which the proposition is intended to convey. Whenever the word "not" is used either before or after the word "all," it is usually the distributive meaning of the word that is employed. Thus "Not all taxpayers are voters" is a proposition which should be put into the following form: "Some (taxpayers) are not (voters) O" and the proposition "All is not lost" should be written "Some (things) are not (those that are lost) O."

The word "only" when used at the beginning of a proposition indicates a negative meaning. Thus "Only the brave deserve the fair" means that people who are not brave are excluded from the class of those who deserve the fair. Stated in logical form the proposition would be "No (people who are not brave) are (Those who deserve the fair) E." And similarly, the proposition "Only the ignorant despise knowledge" should be written "No (people who are not ignorant) are (those who despise knowledge) E." The same type of meaning is indicated by the use of the word "except" in a proposition. For example, "No persons except those trained in mathematics understand the theory of relativity," should be expressed as follows: "No (people who are not trained in mathematics) are (those who understand the theory of relativity) E."

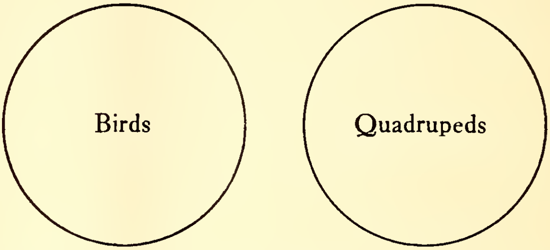
A proposition which contains the words "none but" is another example of the "exceptive" type with which we have been dealing. "None but the ignorant despise knowledge" is a universal negative proposition and should be written in logical form as follows: "No (non-ignorant persons) are (those who despise knowledge) E." Propositions which contain the word "alone" are similar in meaning. For example, "Courageous persons alone are deserving of honors" should be written as follows: "No (persons who are not courageous) are (persons deserving of honors) E." All of these exceptive propositions can be transposed and written as universal affirmatives. The examples used in this paragraph would then be written as follows: "All (persons who despise knowledge) are (ignorant persons) A" and "All (persons who are deserving of honors) are (courageous persons) A." Propositions which contain the words "only" and "except" may be treated in the same way.

Distributed and Undistributed Terms. A term is said to be distributed whenever it is used in its widest extension, or in other words, when it refers to the entire class that is denoted by it. Terms are undistributed when they are not used in their widest extension or when they refer to only a part of the class denoted by them. In propositions that are universal, the *subject term* is always distributed. In negative propositions the *predicate term* is always distributed. Particular propositions always have their subject term undistributed, and in affirmative propositions the predicate term is undistributed, except in the case of universal affirmative propositions in which the extension of the subject term coincides with the extension of the predicate term. These statements concerning the distribution of terms in the A, E, I, and O propositions and the reasons upon which they are based will be obvious if one stops to consider the meaning of each of these four types of proposition. A universal affirmative proposition may be represented by two circles, one of which is included in the other. For example, the proposition "All metals are elements" may be represented in the following manner:



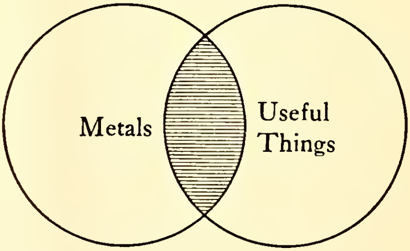
Since the whole class of "metals" is equal to only a part of the class of "elements," the latter term is undistributed while the former is distributed.

A universal negative proposition means that the class of objects denoted by the subject term is excluded from the class denoted by the predicate term. To illustrate we may represent the proposition "No birds are quadrupeds," as follows:



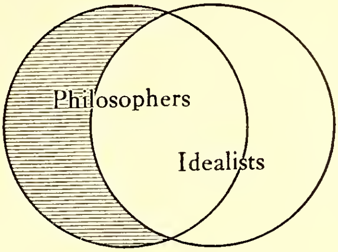
Since each term is used in its widest extension and refers to the entire class of objects both subject term and predicate term are distributed.

Propositions that are particular and affirmative may always be represented by two circles which overlap. Thus the proposition "Some metals are useful" may be represented in this way:



Since neither term refers to the entire class but only to a part of it we say that they are both undistributed.

Particular negative propositions mean that a part of the class denoted by the subject term is excluded from the entire class denoted by the predicate term. As an example we may take the proposition "Some philosophers are not idealists." This meaning would be represented by the use of circles, as follows:



The subject term is here represented by the shaded portion of the circle of philosophers. Since reference is made to only a part of the circle the subject term is undistributed. The circle of idealists is however used in its widest extension and for this reason we may say that the predicate term in an O proposition is always distributed. It is possible for the subject term in an O proposition to refer to a class of objects all of which lie outside the class denoted by the predicate term. "Some cats are not dogs" is a particular negative proposition which could be represented by two circles which do not overlap. Reference is made however to only a part of the class of "cats," but to the entire class of "dogs." Hence the distribution of terms in this proposition does not differ from that of the other one which we considered.

In the case of the A proposition there are some instances in which the two circles representing the subject and predicate terms would coincide. This is true of the proposition "All equiangular triangles are equilateral triangles." Obviously the extension of one term is exactly equivalent to that of the other. Hence the predicate term in this type of a proposition is distributed.

The following rule may be helpful for keeping in mind the distribution of terms in the A, E, I, and O propositions.

Universals distribute their subjects.
Particulars do not.
Negatives distribute their predicates.
Affirmatives do not.

The single exception to this rule occurs in the A proposition when the extension of the subject and predicate terms happen to coincide.

Propositions which do not imply the existence of objects. In general it will be understood that the propositions which have been used in this chapter for purposes of illustration have reference to objects which exist in the outside world. Thus the proposition, "All metals are elements," will be understood to imply that there are metals and that there are elements. "No birds are quadrupeds," will be taken to mean that both birds and quadrupeds do exist. In a similar manner particular propositions will be understood to imply the existence of particular objects.

But it is not true that all propositions imply the existence of objects. Some of them may affirm that certain relations exist between ideas which do not correspond with any objects in the world of our experience. Thus, "A point has no magnitude," is a logical proposition but it does not imply the actual existence of points. "A man who is morally perfect will make no mistakes," is another proposition which does not mean that there are any morally perfect persons in the world. It means, rather, that if a morally perfect man should exist he would have this characteristic. "A reign of universal peace is desirable," does not carry the implication that universal peace is or ever has been in actual existence.

It is important then to make a clear distinction between those propositions which do imply the existence of objects and those which do not. Clearly, inferences which can be drawn from one of these types of propositions will not be valid for the other type. Propositions which do have reference to actual objects may be designated as *existential* propositions, and those which do not have this reference may be called *definitive* propositions. Particular propositions will always be of the existential type. Universal propositions may or may not be of this type. They do not necessarily have reference to actual objects. Whenever a question arises concerning the validity of an inference which is drawn from a universal proposition, it will help to avoid confusion if one will first determine whether the proposition is being used in an existential or in a definitive sense.

Propositions expressing other relations. All that has been said in this chapter about the logical form of propositions and the distribution of terms applies only to those propositions which express the relation of inclusion or exclusion concerning the subject and predicate terms. But, as we have stated before, propositions may express other relations than this one. They may express relations of quantity such as "greater than," "less than," or relations of direction such as "west of," "north of," etc. They may express relations of time such as "before" and "after" or family relations such as "father of," "descendant of," etc., or any one of several other kinds of relation. The most general way of classifying these relations is with reference to their *symmetry* and their *transitiveness*. Relations are said to be symmetrical when they are of the type that if A stands in a certain relation to B, then B stands in the same relation to A. Relations of identity, equality, distance from, etc., are *symmetrical* relations. "All the angles of a triangle are equal to two right angles" warrants the proposition "Two right angles are equal to the sum of all the angles of a triangle." In other words the subject term is related to the predicate term in exactly the same way as the predicate term is related to the subject term. Other propositions which illustrate the symmetrical relation are "The town A is located five miles from town B," "Water is H_2O," and "The government of the United States is similar to the government of Great Britain."

A relation is asymmetrical when it is of the type that if A stands in a certain relation to B, then B does not stand in the same relation to A. Relations of "more," "less," "direction," and certain types of family relation belong to this class. Thus "Omaha is west of Chicago" is a proposition in which the relation expressed is asymmetrical. The same is true of each of the following propositions; "John is the grandson of Mr. Smith," "Gold is heavier than tin" and "Ten o'clock p.m. is later than eight o'clock p.m." In all of these cases the predicate term stands in a different relation to the subject term than is true of the reverse relationship. The relation of inclusion which is expressed in the universal affirmative proposition is symmetrical when the extension of subject and predicate terms coincide, but when they do not the relation is asymmetrical. The relation of exclusion is symmetrical in the universal negative propositions but it is asymmetrical in those that are particular and negative.

Transitive relations are such that if a term A stands in a certain relation to B, and B stands in the same relation to C, then A also stands in that same relation to C. Intransitive relations are those in which this set of relations does not hold true. In other words intransitive relations are such that the first term in the series does not stand in the same relation to the third term as it does to the second term. For example, in the propositions "Five is greater than four, and four is greater than three, hence five is still greater than three" the relation involved is of the transitive type. But in the case of "Henry is the father of John, and John is the father of Charles, therefore Henry is the grandfather of Charles" the relation is intransitive.

QUESTIONS AND EXERCISES

1. What is a logical proposition? How does it differ from a judgment? from a grammatical sentence? Give examples of sentences which are not propositions.
2. How does a hypothetical proposition differ from a categorical proposition? Name two kinds of conditional propositions. Illustrate each. What is meant by each of the following: antecedent, consequent, alternatives?
3. Explain the way in which terms, relations, and qualifying words are used in a categorical proposition. What is meant by the relation of exclusion or inclusion? What other relations may be used in categorical propositions?
4. What is meant by the quality and the quantity of categorical propositions? How can you determine whether a proposition is universal? particular? negative? affirmative?
5. Explain the distributive and the collective use of the word "all." Give examples of each.

6. What is meant by saiyng that a term is distributed? Which terms are distributed in the A, E, I, and O propositions respectively? Under what condition is the predicate of a universal affirmative proposition distributed? Give an example.
7. Explain the distinction between existential and definitive propositions. Give examples of each.
8. Are propositions which belong to the field of mathematics definitive propositions? Give reasons for your answer.
9. How can one determine whether a given proposition is used in an existential or a definitive sense?
10. When is a relation said to be symmetrical? asymmetrical? transitive? intransitive? Give examples of each of these four kinds of relations.
11. Show how each one of the examples given above could be expressed in terms of the relation of exclusion or inclusion.
12. Put the following propositions in strict logical form taking care to observe the instructions given in the chapter for this procedure:

(1) All those present constitute the class in Logic.
(2) Nearly all the troops have left the town.
(3) Great is Diana of the Ephesians.
(4) Only the brave deserve the fair.
(5) Everyone is a good judge of his own interests.
(6) Uneasy lies the head that wears the crown.
(7) Not every mistake is a proof of ignorance.
(8) Metals are all good conductors of heat.
(9) Few men achieve excellence.
(10) Only the ignorant despise knowledge.
(11) Socrates was the wisest man in Athens.
(12) Talents are often misused.
(13) Only those who are tax-payers can vote at this election.
(14) Rivers generally run into the sea.
(15) Nothing is beautiful except truth.
(16) Some stories that are true are not interesting.
(17) No morons are capable of doing college work.
(18) Not all men are liars.
(19) All is not lost.
(20) A line has no width.
(21) A Republic is a government by the people.
(22) A few of the apples in this basket are spoiled.
(23) All the angles of a triangle are equal to two right angles.
(24) All of the bricks in this building are red.

(25) Few textbooks are free from error.
(26) All of the students in this class will not receive a high grade.
(27) In Plato's *Republic* none but philosophers have the right to be rulers.
(28) To be logical means to be consistent.
(29) Napoleon was the Emperor of France.
(30) Nine plus seven equals sixteen.
(31) Only those who are willing to work are likely to succeed.
(32) Nothing is sacred but the integrity of one's own mind.

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CHAPTER VII

IMMEDIATE INFERENCE

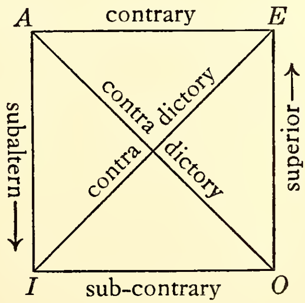
Definition of Immediate Inference. Inference may be defined as that process of the mind by which we go from one part of a system of facts or ideas to another part of the same system. Inference, like logic, has to do with the orderly arrangements of the universe. In fact the two terms "inference" and "logical procedure" mean very nearly the same thing. Both of them presuppose a systematic arrangement of parts and they are both possible wherever such an arrangement exists. Knowledge in any particular field is built up through the discovery of systematic relations which so unite the particular facts that it is possible on the basis of what is known concerning some of them to infer certain truths concerning the rest.

As pointed out in Chapter II, inferences are of two kinds, inductive and deductive. Although these two types of inference as they are employed in any field of science are mutually interdependent, we distinguish between them by saying that induction begins with particular facts and proceeds to a general conclusion, while deduction begins with a general or universal proposition and proceeds to some particular application of it. Deductive reasoning may be further divided into two classes, known as *mediate* inference and *immediate* inference. Mediate inference is that type in which the conclusion is obtained not directly but by a process of comparison in which two terms are related to each other through the medium of a third term which is common to both of the others. In all cases of mediate inference it is necessary to have two propositions as a basis for the conclusion. This is the type of inference which one finds in the syllogism.

Immediate inference on the other hand, is that type in which the conclusion does follow directly from the single proposition with which one begins. For example, if we take as our starting point the proposition "All men are mortal," we can infer directly that "No men are non-mortal" and that "Some mortal beings are men." We can also infer that "Some men are mortal" and that "No non-mortals are men." No two of these propositions have the same meaning, and yet, if the first one be true, all the rest of them must be true. And if we grant that our original proposition be true we can infer not only that certain other propositions will be true but that certain ones will be false. If we know that "All men are mortal" is a true proposition, we can be sure that the propositions "No men are mortal" and "Some men are not mortal" are both false. This process of deriving a conclusion from a single proposition without the medium of some common or middle term is what is meant by immediate inference. There are several kinds of immediate inference, the most important of which are as follows: inference by (1) opposition, (2) obversion, (3) conversion, (4) contraposition, and (5) inversion. These will now be considered in the order named.

Inference by Opposition. By the opposition of propositions is meant any logical relationship existing between propositions having the same subject term and the same predicate term. These include what is known as the *contrary*, *contradictory*, *subaltern*, *sub-contrary* and *superior* relations. Propositions are said to be "contrary" when they are opposite in meaning and of such nature that if one of them is true the other one will be false, but it is possible for both of them to be false. Or, to state the same meaning in another way, we may say that contrary propositions are propositions having the same subject term and the same predicate term of which both are universal in quantity but they differ in quality. Thus, "All metals are elements" and "No metals are elements" are contrary propositions. Contradictory propositions are also opposite in meaning but they are so related to each other that if one is true the other is false, and if one is false the other is necessarily true. Or, we may define contradictory propositions as those which have the same subject term and the same predicate term but which differ in both quality and quantity. Thus "All men are rational beings" and "Some men are not rational beings" are contradictory propositions, and the same is true of "No Americans are Europeans" and "Some Americans are Europeans."

The subaltern relation exists between any universal proposition and the particular proposition included in it. In other words the subaltern of any proposition differs from the original only in the matter of quantity. Thus "Some heroes are brave men" is the subaltern of "All heroes are brave men," and "Some men are not immortal beings" is the subaltern of "No men are immortal beings." In each of these cases the particular proposition is called the subaltern of the universal, and the universal is in turn called the *superior* of the particular proposition which it includes. Sub-contrary propositions are both particular in quantity, but they differ in quality. "Some things that glitter are gold" and "Some things that glitter are not gold" are sub-contrary propositions. Their relation to each other is similar to that which exists between contrary propositions, but, since sub-contraries are always particular, it does not follow that if one is true the other is necessarily false. Sub-contraries may both be true, or they may both be false, and it is possible for one of them to be true and the other one to be false. The various relations which the opposition of propositions includes may be indicated by the traditional Aristotelian square, as follows:



Summarizing, we may say that the opposition of propositions has to do with the relationships which exist between propositions having the same subject term and the same predicate term. Whenever this condition has been met, the A and E propositions are known as contraries; the A and O are contradictories, and the same is true of the E and I. The O and I propositions are known as sub-contraries; the I and O are the subalterns of the A and E respectively, and the A and E are the superiors of the I and O respectively.

It is on the basis of what is known concerning these relationships that immediate inference by opposition is possible. Suppose, for example, that a given proposition is an O and we know that it is false. We can then infer directly that the A proposition is true, since A is always the contradictory of O. We can infer further that proposition E will be false since it is the contrary of A. And since A is true we know that its subaltern I will be true, for whenever a universal proposition is true its subaltern must also be true. The truth of proposition I could also be inferred from the fact that its contradictory or E is false. In a similar manner if we grant that proposition E is true, we can infer that A is false, the contradictory of A which is O will be true and I which is the contradictory of E will be false. If a particular proposition be true, its superior may be either true or false, but if the subaltern be false, its superior must also be false.

Obversion. We have already noted that propositions are meaningful only in so far as they refer to a system of objects and relations. Indeed it is the systematic character of knowledge which constitutes the basis or ground for all kinds of inference. As we have stated before, any given proposition, if it be true, must belong to a system of propositions all of which must likewise be true. Immediate inference includes those processes by which we go from an original proposition to any of the other propositions that belong to the same system of which the first one was a part. One of these processes is known as obversion. To obtain the obverse of any proposition it is necessary to do two things, (1) *change the* *quality of the proposition,* and (2) *change the predicate term* by putting in its place the *logical contradictory* of the original predicate term. For example, the proposition "Uneasy lies the head that wears a crown" may be put into logical form as "All (heads that wear crowns) are (those that are uneasy) A" and obverted as follows: "No (heads that wear crowns) are (those that are easy) E." "Those who do not pay their taxes are not allowed to vote" when put into logical form would appear as follows: "No (non-taxpayers) are (voters) E"; and the obverse would be "All (non-taxpayers) are (non-voters) A." A particular proposition such as "Not all men are liars" put into logical form would be "Some (men) are not (liars) O"; and the obverse of this proposition is "Some (men) are (non-liars) I." The obverse of "Some (plants) are (poisonous) I" is "Some (plants) are not (non-poisonous) O." It should be noted that in the process of obversion the subject term is not changed at all. It should also be noted that in the case of particular propositions the change of quality is always indicated in the copula by adding the word "not" or by omitting it, whereas in the case of universal propositions this change is indicated by substituting *no* for *all* or vice versa. Care should also be exercised in the matter of changing the predicate term to make sure that it is changed to its logical contradictory.

From the examples of obversion that have been given it will be seen that whenever an original proposition is affirmative, its obverse will be negative and vice versa. This indicates that every proposition has two meanings, an affirmative one and a negative one, and it is always possible to infer from one of them what the other one is.

Conversion. The converse of a proposition is obtained by interchanging the position of the subject term and the predicate term. Thus the proposition "Men are not immortal beings" may be put into logical form as "No (men) are (immortal beings) E," and converted as follows: "No (immortal beings) are (men) E." "Some metals are extremely useful" when stated in logical form appears as "Some (metals) are (extremely useful things) I," and this may be converted as follows: "Some (extremely useful things) are (metals) I." The original proposition in each of these cases is known as the "convertend" to distinguish it from the second or "converse" statement.

There are two types of conversion, one of which is known as *simple conversion* and the other one as *conversion by limitation.* The examples given in the paragraph above illustrate simple conversion. This type is always used in the case of E and I propositions and sometimes it is used in the case of A propositions. It involves only an interchanging of the position of the subject term and the predicate term and does not affect the quality or the quantity of the proposition. Simple conversion is used in the case of A propositions whenever the subject term and the predicate term coincide so far as their extension is concerned. For example, in the proposition "All equiangular triangles are equilateral triangles" it is obvious that the extension of the subject term is exactly equivalent to the extension of the predicate term. The same thing is true of the proposition "Gold is the most precious of metals." Propositions of this kind are converted by the simple method. The converse of our first example is "All (equilateral triangles) are (equiangular triangles) A" and of our second one "All (the most precious of metals) is (gold) A." No change is made in either of the terms or in the quality or quantity of the proposition. The only change that is made from the original proposition has to do with the position of the two terms.

Conversion "by limitation" is used only in the case of an A proposition in which the extension of the subject term does not coincide with the extension of the predicate term. It is necessary then to change the quality of the proposition from universal to particular. A general rule which applies to cases of this kind is *"If a term is not distributed in the convertend, it cannot be distributed in the converse."* Hence propositions which are converted by limitation are always changed from A to I. For example, the proposition "All metals are elements" when converted reads as follows, "Some (elements) are (metals) I"; and the converse of

"State universities are institutions of higher learning" is "Some (institutions of higher learning) are (state universities) I."

It is always possible to convert an A, E, or I proposition but the O proposition will not yield the converse. The reason for this is that an O proposition indicates that a part of the class of objects denoted by the subject term lies outside the entire class denoted by the predicate term, but the remaining part of the class denoted by the subject may or may not be included in the predicate term.

Contraposition. The contrapositive of a proposition is that form in which the contradictory of the original predicate term is used as the subject term of the proposition. This form may be obtained by obverting the original proposition and then converting the result. For example, the contrapositive of "All cruel men are cowards" is obtained in the following manner: (1) *by obverting the original proposition* we get "No (cruel men) are (non-cowards) E," and (2) *by converting the result* we obtain "No (non-cowards) are (cruel men) E." If the original proposition be universal and negative as in the case of "No Democrats are advocates of high tariff," the obverse would be "All (Democrats) are (those who do not advocate a high tariff) A," and the contrapositive would be the converse of this or "Some (those who do not advocate a high tariff) are (Democrats) I." Again, "Some (mistakes) are not (intentional) O" when obverted is written "Some (mistakes) are (non-intentional) I," and the converse of this or the contrapositive of the original is "Some (non-intentional things) are (mistakes) I." The contrapositive may be obtained in the case of any A, E, or O proposition. The I proposition however does not yield the contrapositive. The reason for this is that an I proposition when obverted becomes an O, and, as we have stated before, the O proposition cannot be converted.

Contrapositives are of two kinds, *partial* and *full*. They are distinguished by the fact that in the partial contrapositive the subject term of the original proposition is used as the predicate term of the contrapositive, but in the full contrapositive it is the contradictory of the original subject term which is used as the predicate term. In both cases, however, it is the contradictory of the original predicate term which is used as the subject. For example, if the original proposition be "All triangles are three-sided figures," the partial contrapositive would be "No (non-three-sided figures) are (triangles) E," and the full contrapositive would be "All (non-three-sided figures) are (non-triangles) A." The full contrapositive may always be obtained by obverting the partial contrapositive.

Inversion. The inverse of a proposition is that form which has for its subject term the contradictory of the subject term of the original proposition. The partial inverse will have the same predicate term as the original proposition, and the full inverse will have for its predicate term the contradictory of the original predicate term. The full inverse is always the obverse of the partial inverse and *vice versa.* Only universal propositions yield the inverse form. In the case of A propositions the procedure for obtaining the inverse is as follows: obtain the full contrapositive of the original proposition and convert the result. This will give the full inverse form. The partial inverse may then be obtained by obverting the full inverse. The inverse of E propositions cannot be obtained in this way since the full contrapositive of an E will be an O, and the O proposition cannot be converted. To obtain the inverse of an E it is necessary to convert the original proposition and obvert the result. This will give one the obverted converse. The partial inverse may then be obtained by converting this form. By obverting once more the full inverse may be obtained.

Summary Tables. The immediate inferences discussed in this chapter may be summarized by the following tables.

I *The Opposition of Propositions*

Original	All (Quakers) are (pacifists) A
Contrary	No (Quakers) are (pacifists) E
Contradictory	Some (Quakers) are not (pacifists) O
Subaltern	Some (Quakers) are (pacifists) I
Original	No (Indians) are (Eskimos) E
Contrary	All (Indians) are (Eskimos) A
Contradictory	Some (Indians) are (Eskimos) I
Subaltern	Some (Indians) are not (Eskimos) O
Original	Some (sheep) are (black) I
Sub-contrary	Some (sheep) are not (black) O
Contradictory	No (sheep) are (black) E
Superior	All (sheep) are (black) A
Original	Some (Christians) are not (Catholics) O
Sub-contrary	Some (Christians) are (Catholics) I
Contradictory	All (Christians) are (Catholics) A
Superior	No (Christians) are (Catholics) E

II *The Form of Some of the Immediate Inferences*

S represents the subject term and P the predicate term of an original proposition. The form for the particular inferences which we have discussed may then be indicated as follows:

Original	S.	P
Converse	P.	S
Obverse	S.	non P
Obverted Converse	P.	non S
Partial Contrapositive	non P. . .	S
Full Contrapositive	non P. . .	non S
Partial Inverse	non S. . .	P
Full Inverse	non S. . .	non P

Since the predicate term of a proposition may be changed to its contradictory by obverting, and the subject and predicate terms may be interchanged by converting, it follows that any of these forms which are possible may be derived from an original proposition by the alternate processes of obverting and converting until the desired term is obtained in the position that is wanted.

III *Examples of Immediate Inferences*

Original	All (lions) are (wild animals) A.
Converse	Some (wild animals) are (lions) I.
Obverse	No (lions) are (non-wild animals) E.
Partial Contrapositive	No (non-wild animals) are (lions) E.
Full Contrapositive	All (non-wild animals) are (non-lions) A.
Full Inverse	Some (non-lions) are (non-wild animals) I.
Partial Inverse	Some (non-lions) are not (wild animals) O.*

Original	No (aliens) are (voters) E.
Obverse	All (aliens) are (non-voters) A.
Converse	No (voters) are (aliens) E.
Partial Contrapositive	Some (non-voters) are (aliens) I.
Full Contrapositive	Some (non-voters) are not (non-aliens) O.
Obverted Converse	All (voters) are (non-aliens) A.
Partial Inverse	Some (non-aliens) are (voters) I.
Full Inverse	Some (non-aliens) are not (non-voters) O.

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* In this example of the partial inverse there seems to be a violation of the general rule for immediate inferences, viz., that a term which is undistributed in the original proposition cannot be distributed in any of the propositions inferred from it. Here we have the term "wild animals" distributed in the partial inverse. The explanation lies in the fact that the original proposition "All lions are wild animals" is understood to imply the existence of a class of objects known as lions. In other words this is an existential proposition. This being true, it follows that since the class known as lions is included in the class of objects known as wild animals, there are other objects which are not included in that class. Hence, "All lions are wild animals" interpreted as an existential proposition implies that "some things are not wild animals." This type of inference, valid for all existential propositions, does not hold true for definitive propositions.

Original	Some (soldiers) are (brave men) I.
Obverse	Some (soldiers) are not (non-brave men) O.
Converse	Some (brave men) are (soldiers) I.

Original	Some (business men) are not (successful) O.
Obverse	Some (business men) are (non-successful) I.
Partial Contrapositive	Some (non-successful men) are (business men) I.
Full Contrapositive	Some (non-successful men) are not (non-business men) O.

Special Types of Immediate Inference. It is possible to infer one proposition from another by adding a special qualifying or limiting word to both the subject term and the predicate term. It is important that the same limiting word or determinant be used in connection with each term and that it be used in the same sense in both cases. This is known as inference by *added determinants.* As an example, we may infer from the proposition "All men are mortal" that "All white men are white mortals." And from "All bankers are business men" we may infer that "All American bankers are American business men." Again it is possible to infer one proposition from another by using both the subject term and the predicate term as parts of a more complex conception. This is known as *inference by complex conception.* Thus from the proposition "Texas is the largest state in the union" we may infer that "The capital of Texas is the capital of the largest state in the union"; and from "All horses are animals" we may infer that "The head of a horse is the head of an animal."

Propositions which express some relation other than exclusion and inclusion may be converted directly by interchanging the subject and predicate terms and making the converse relation between them opposite in meaning and direction from the one given in the convertend. Thus "Chicago is east of Denver" may be converted by saying "Denver is west of Chicago." "A long ton is more than a short ton" yields for its converse "A short ton is less than a long ton." The converse of "John is the father of Charles" is "Charles is the son of John." For obtaining the obverse, contrapositive or inverse of propositions which express relations of these kinds, one will be more likely to avoid confusion if he first reduces the proposition to one expressing the relation of exclusion or inclusion and then proceeds in the regular manner.

QUESTIONS AND EXERCISES

1. What is an inference? Distinguish between mediate and immediate inference. Give an example of each. Mention as many kinds of immediate inference as you can.
2. Explain what is meant by "inference by opposition." Show how this type of inference may be indicated by means of the Aristotelian square.
3. Define and illustrate: contrary propositions, contradictory propositions, subcontrary propositions, the subaltern relation.
4. State the rule for obtaining the obverse of a proposition; the converse; the partial contrapositive; the full contrapositive; the full inverse when the original is an A proposition; the partial inverse when the original is an E proposition.
5. Using S to indicate the original subject and P the original predicate, determine the subject and predicate terms of the converse, obverse, partial contrapositive, full contrapositive, partial inverse, and full inverse.
6. Explain fully and illustrate (1) inference by added determinants, (2) inference by complex conception.
7. State in logical form and give in the order named: contrary, contradictory, and subaltern (or superior) of each of the following propositions:
   (1) All bullies are cowards.
   (2) Some who speak much are not those who speak well.
   (3) Only those who work hard will succeed.
   (4) Leopards cannot change their spots.
   (5) Some animals are ferocious.
   (6) Few men are able to do this.
8. If an O proposition is false, determine logically the truth or falsity of A, E, and I.
9. State in logical form and give (1) the obverse and (2) the converse (when possible) of the following propositions:

(1) Universities are institutions of higher learning.
(2) All bacteria are not harmful.
(3) Planets do not shine by their own light.
(4) All emotions are mental states.
(5) Some defeats are in reality victories.
(6) Few logicians are free from error.
(7) Not all who came to scoff remained to pray.
(8) A triangle is bounded by three straight lines.
(9) Only those who are of age can vote.
(10) Some fruits are not good to eat.
(11) No illiterate persons can enter college.
(12) Some physicians are not competent.
(13) All criminals are dangerous characters.
(14) Parallel lines do not meet.
(15) Whoever understands this can explain it.

10. Write the partial and full contrapositive of all the propositions in No. 9 of which these forms can be given.
11. Write the partial and full inverse wherever possible for the propositions in No. 9.
12. Write a list of propositions expressing relations other than that of exclusion or inclusion. State the converse of each one.
13. In the partial inverse of an A proposition there seems to be an error due to the fact that the predicate term is distributed but in the original proposition it is undistributed? Explain. Does the inference hold for all A propositions? Explain.
14. From your reading, attendance at lectures, or private conversations, select examples of illogical obversions.
15. In the same way select examples of illogical conversions.

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CHAPTER VIII

THE CATEGORICAL SYLLOGISM

The Nature of the Syllogism. The syllogism is a logical device by means of which it is possible to determine the relationship of two terms to each other on the basis of their respective relations to some third term. As an instrument of thinking it was first used by Aristotle. He regarded it as the form of reasoning necessarily implied in all types of demonstrative inference. Since his time, many additions and modifications have been made to his original doctrine of the syllogism, but in spite of these it still remains one of the most important elements in the science of logic. Syllogistic inference differs from the type which was considered in our previous chapter in that the conclusion reached is not obtained directly from a single proposition, but is drawn from two propositions which have one term in common. This type of inference is called *mediate* to distinguish it from *immediate* inference which is characteristic of the interpretation and opposition of propositions.

There are various kinds of syllogisms. Classified according to the type of proposition which constitutes the major premise of the syllogism, they are known as *categorical*, *hypothetical*, and *disjunctive*. Classified according to the type of relation expressed in the propositions that go to make up the syllogism, they are known as *transitive*, *intransitive*, *symmetrical* and *asymmetrical*. The simplest type of categorical syllogism is the one in which the relation expressed between the terms of each proposition is that of exclusion or of inclusion. Since this is true, it will be appropriate to begin our study of the categorical syllogism by giving attention to this particular type.

A categorical syllogism is made up of three propositions known respectively as the *major premise*, the *minor premise*, and the *conclusion*, and these occur in the order named whenever the argument in question has been reduced to its strict syllogistic form. Each of the propositions in a categorical syllogism contains two terms, and each one of the terms occurs twice in the syllogism. These terms are known as the *major term*, the *minor term*, and the *middle term*. These terms are defined with reference to the conclusion of the syllogism. The conclusion is the proposition in the syllogism which is supported by reasons. It is usually introduced by the word *therefore* or its equivalent. The premises, on the other hand, are asserted directly without proof. The major term in a syllogism is the predicate term of the conclusion. The minor term is the subject term of the conclusion. The premise which contains the major term is the *major premise* and the premise which contains the minor term is the *minor premise*. The middle term is not contained in the conclusion but it occurs in each of the two premises.

From these statements and definitions it follows that in order to determine the major premise or the minor premise, or any other part of a syllogistic argument, one must begin by examining the conclusion. Since the predicate of the conclusion is by definition the major term, the major premise can then be located by finding the premise in which this term occurs. And since the subject of the conclusion is by definition the minor term, the minor premise can likewise be located by finding the premise which contains this term. Take for example the following argument: "All human productions are liable to error, and therefore all books, which are human productions, are liable to error." The conclusion in this case is "All books are liable to error" since this is the one proposition in the argument the reasons for which are stated. The major term is then "liable to error" and the minor term is "books." The proposition "All human productions are liable to error" contains the same term as the predicate of the conclusion and is therefore the major premise. And "All books are human productions" is the minor premise, since it contains the subject term of the conclusions. Arranging these propositions in their proper order for the syllogism we have:

middle term	*major term*	
All (human productions)	are (liable to error) A.	*major premise*
minor term	*middle term*	
All (books) are	(human productions) A.	*minor premise*
minor term		
∴ All (books) are	(liable to error) A.	*conclusion*

Or, to take an example in which the relation of exclusion rather than inclusion is expressed, "Brutes are not morally responsible beings since they are not rational as all morally responsible beings are." Arranging these propositions in syllogistic form, as we did in the previous example, we have

major term	*middle term*	
All (morally responsible beings)	are (rational) A.	*major premise*
minor term	*middle term*	
No (brutes) are	(rational) E.	*minor premise*
minor term	*major term*	
∴ No (brutes) are	(morally responsible beings) E.	*conclusion*

Rules of the Syllogism. The following rules apply to the use of the syllogism. A violation of any one of them renders the conclusion invalid.

1. *A logical syllogism contains three terms and only three, and these must be used in the same sense throughout the argument.* This rule is necessary since the syllogism is a means for comparing two terms with a third term which is common to the two premises. In the syllogism "All metals are elements; gold is a metal; and therefore, it is a metal" we may say that the conclusion represents a true inference because the two terms "gold" and "elements" are compared with a third term "metals." This process of comparison would obviously be impossible if the syllogism contained more or less than three terms. A frequent violation of this rule occurs whenever a term is used with two meanings, one of which is implied in one part of the argument and the

other one in another part of the argument. This is equivalent to four terms since four meanings are used in the argument.

2. *The middle term in the syllogism must be distributed at least once.* It is sometimes possible for the middle term to be distributed twice, but it is always necessary to have it distributed once. The reason for this is that the middle term serves as a standard or means of comparison for the major and the minor terms, and, unless the medium of comparison is used in its widest or its full extension, one cannot be sure that the other two terms are being compared with the same thing. In the example used above it would be impossible for one to be sure that "gold" and "elements" were compared with the same thing unless the term "metals" was used in its widest extension. The violation of this rule is known as the *fallacy of undistributed middle.*

3. *No term can be distributed in the conclusion unless it is distributed in the premise in which it occurs.* This means that a term cannot be used in its widest extent in the conclusion if it was used in a narrower sense in its premise. In other words if the premise refers to only a part of a class of objects, no conclusion can be drawn concerning the entire class to which those objects belong. When this rule is violated with reference to the major term, the fallacy is known as *illicit major;* when violated with reference to the minor term, the fallacy is called *illicit minor.*

4. *One of the premises must be affirmative.* No conclusion can be drawn from two negative premises. Since the relation expressed in a negative proposition is that of exclusion, it follows that no medium of comparison is possible in the case of two negative premises. The fallacy in this case is known as *two negatives.*

5. *If one premise is negative, the conclusion must be negative.* Whenever the relation of exclusion is expressed in one of the premises, it is quite obvious that the same relation must characterize the conclusion.

From these five rules it is possible to deduce two corollaries which also hold good with reference to the syllogism. They are as follows:

(1) *If one premise is particular the conclusion must be particular.*

(2) *No conclusion can be drawn from two particular premises.* At least one of the premises must be universal.

The violation of either of these two corollaries will result in a fallacy. The fallacy will be an undistributed middle term or an illicit major or minor term.

The Figures of the Syllogism. Since the middle term in a categorical syllogism is found in both the major and the minor premise and in each of these it may be either the subject term or the predicate term, it follows that there are four possible positions which the middle term may occupy. Each of these positions constitutes what is known as a *figure* of the syllogism. Using the letter P to represent the major term (predicate of conclusion) and the letter S to represent the minor term (subject of conclusion) and representing the middle term by the letter M, we may indicate the four figures of the syllogism in the following way:

FIG. I		FIG. II		FIG. III		FIG. IV	
M	P	P	M	M	P	P	M
S	M	S	M	M	S	M	S
S	P	S	P	S	P	S	P

The first figure is the one most commonly used, and it is the only one from which it is possible to draw a universal affirmative conclusion. Aristotle called it the *perfect figure* and insisted that arguments of any other figure be reduced to that particular form. As a concrete example of the first figure we may cite the following argument:

All (idealists) are (followers of Plato) A.
All (this man) is (an idealist) A.
∴ All (this man) is (a follower of Plato) A.

The second figure is the one in which the middle term is predicate in both of the premises. Since the middle term must be distributed in one of the premises and only negative propositions distribute their predicates, it follows that all valid arguments of the second figure will contain one negative premise. The following will serve as an example:

All (men) are (rational beings) A.
No (brutes) are (rational beings) E.
∴ No (brutes) are (men) E.

In the third figure the middle term is subject in both of the premises. For example:

All (books) are (liable to error) A.
All (books) are (human productions) A.
∴ Some (human productions) are (liable to error) I.

In the fourth figure the position of the middle term is the reverse of what it is in the first figure. The following is a concrete example:

Some (that which gives one satisfaction) is (a clear conscience) I.
All (a clear conscience) is (something other than wealth) A.
∴ Some (that which is not wealth) is (that which gives one satisfaction) I.

The Valid Moods of the Categorical Syllogism. The mood of a categorical syllogism is made up of three letters (A, E, I, or O) which denote the quality and quantity of the propositions used and in the order in which they occur in the syllogism. For example, a syllogism in which all three of the propositions used are universal affirmative, is said to have the mood AAA. Or, if the major premise is a universal negative, the minor premise a universal affirmative and the conclusion a universal negative, the syllogism has the mood EAE. Since there are only four kinds of propositions which may be used in the categorical syllogism we may list the possible combinations which may be used as premises as follows:

AA	EA	IA	OA
AE	EE	IE	OE
AI	EI	II	OI
AO	EO	IO	OO

Although all of these combinations are possible in a syllogism, some of them do not yield a valid conclusion. We know from our rules of the syllogism that no valid conclusion can be drawn from two negative premises, and we also know that a valid conclusion cannot be obtained from two particular premises. If then we omit from our list all of those combinations in which we have either two negatives or two particulars, we have the following possible combinations from which valid conclusions may be obtained:

AA	EA	IA	OA
AE		IE	
AI	EI		
AO			

Not all of these combinations will yield valid conclusions in each of the four figures. Since the figure of the syllogism is determined by the position of the middle term in the two premises, we can determine at once certain rules which apply to each of the four figures. They are as follows:

Special Rules for each of the Four Figures

FIGURE I

$$\begin{array}{cc} M & P \\ S & M \\ \hline S & P \end{array}$$

1. *In the first figure the minor premise must be affirmative.*

2. *The major premise must be universal.*

The reasons for the first rule are as follows:

A violation of this rule is bound to involve one in a fallacy. The fallacy will be either illicit major or two negatives. Suppose, for example, that we violate this rule and have a negative proposition for our minor premise. Our conclusion will then be negative, since a negative premise always yields a negative conclusion. The major term will then be distributed for the reason that negative propositions always distribute their predicates. But according to our rules of the syllogism a term cannot be distributed in the conclusion unless it is distributed in the premise in which it occurs. Now if the major premise be affirmative, the major term which is predicate in that premise will be undistributed and this will be an illicit major. If on the other hand the major premise be negative so as to distribute the major term, we will have the fallacy of two negative premises. Because our rule cannot be violated without involving one or the other of these two fallacies it follows that in the first figure the minor premise must be affirmative.

The proof for the second rule is as follows:

Since the minor premise has been proved to be affirmative, we know that the middle term is undistributed in the minor premise. The reason for this is that the middle term is predicate in the minor premise and affirmative propositions do not distribute their predicates. But the middle term must be distributed at least once; so if it is not distributed in the minor premise, it must be distributed in the major premise. Since the middle term is subject in the major premise, that premise must be universal, for only universal propositions distribute their subject terms.

FIGURE II

$$\begin{array}{cc} P & M \\ S & M \\ \hline S & P \end{array}$$

1. *One premise must be negative.*
2. *The major premise must be universal.*

Since in the second figure the middle term is predicate in both of the premises, it follows that one premise must be negative in order to avoid the fallacy of undistributed middle.

Having shown that one premise must be negative it follows that the conclusion will be negative and the major term will be distributed. But if the major term be distributed in the conclusion it must also be distributed in the major premise. Hence the major premise must be universal in order to distribute the major term. A violation of this rule would result in the fallacy of illicit major.

FIGURE III

$$\begin{array}{cc} \mathrm{M} & \mathrm{P} \\ \mathrm{M} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{P} \end{array}$$

1. *The minor premise must be affirmative.*
2. *The conclusion must be particular.*

The proof for the first of these rules is identical with that used for the first figure. If the minor premises be negative, it will involve the fallacy of illicit major or the fallacy of two negatives.

Since the minor premise must be affirmative, the minor term will be undistributed in the minor premise. The reason for this is that the minor term is predicate in its premise and affirmative propositions do not distribute their predicates. But, if the minor term be undistributed in its premise, it must be undistributed in the conclusion. Hence the conclusion must be particular for only particular propositions do not distribute their subjects.

FIGURE IV

$$\begin{array}{cc} \mathrm{P} & \mathrm{M} \\ \mathrm{M} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{P} \end{array}$$

1. *If either premise be negative, the major premise must be universal.*
2. *If the major premise be affirmative the minor premise must be universal.*
3. *If the minor premise be affirmative the conclusion must be particular.*
4. *If the minor premise be particular, the major premise must be negative.*
5. *If the major premise be particular, the conclusion must be affirmative.*

These five rules, like those for the preceding figures, may be proved by applying the rules of the syllogism and the rules which govern the distribution of terms. The violation of any of these five rules for the fourth figure will result in a formal fallacy. The violation of the first rule will result in the fallacy of illicit major. The violation of the second rule yields the fallacy of undistributed middle. When the third rule is violated we have the fallacy of illicit minor. The violation of the fourth rule results in the fallacy of undistributed middle. And when the fifth rule is violated we have the fallacy of illicit major.

The Reduction of Figures. The process of changing an argument from the second, third, or fourth figures to the first figure is known as *reduction.* There are two ways in which these changes are made. The first of these is known as *direct reduction.* It is accomplished by the process of conversion. In the case of the second figure, it is the major premise that is converted ; in the third figure, it is the minor premise ; while in the fourth figure it is necessary to convert both premises. Sometimes it is also necessary to transpose the two premises and to convert the conclusion. The second method which is known as *indirect reduction* requires obversion and the transposition of the premises, or the process known as *reductio ad absurdum.* This latter process is a means of establishing the truth of a conclusion reached in an argument of some figure other than the first by showing that its contradictory is false. As an example of indirect reduction we may consider the case of an argument having the mood OAO of the third figure. Obviously an argument of this type cannot be reduced to the first figure by the direct method since the conversion of the minor premise would involve one in the fallacy of two particular premises. The truth of the conclusion can, however, be established by means of obversion and transposition. Or it can be demonstrated by showing that its contradictory is false since it contradicts the major premise.

The reduction of arguments to the first figure does not have the same importance for the modern logician that it held for Aristotle. Since Aristotle considered all deductive inference to be based upon the so-called *dictum de omni et nullo*,* and since this principle applies directly only to the first figure we can understand his reason for insisting upon the reduction of arguments. But since the principles upon which the other figures are based are also recognized as valid, it is no longer necessary to reduce all arguments to the first figure in order that their validity may be established. Reduction is then for the modern student no more than a logical exercise.†

Syllogisms Dealing with Other Relations. Thus far our discussion of the syllogism has been based almost entirely on the relations of inclusion and exclusion. Our rules of the syllogism which were stated in the discussion of valid moods and statements concerning the figures of an argument are applicable only to those syllogisms which deal with these particular relations. It is true that syllogisms of this type do occur more frequently than those of any other type, and as a general rule it is possible to reduce any type of categorical syllogistic argument to this particular one. But it is not always necessary to make this reduction for it is possible to have a valid syllogism which expresses other relations than that of exclusion or inclusion. The premises and conclusion of a syllogistic argument may express such relations as those of identity, similarity, greater than, father of, west of, better than, and many others. One way of classifying these relations is to call them *symmetrical*, *asymmetrical*, and *non-symmetrical*. As stated in the last part of Chapter VII, relations are said to be symmetrical when if a given class A stands in a certain relation to a class B, then class B stands in the same relation to class A. The relation is said to be asymmetrical when this is not true. Another classification of these relations which cuts across this one is that of *transitive*, *intransitive*, and *non-transitive*. Relations are said to be transitive when if a class A stands in a certain relation to class B, and B stands in the same relation to class C, then A stands in that same relation to C. The relation is said to be intransitive when this is not true and non-transitive when it may or may not be true.

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* The usual statement of this principle is as follows:
"Whatever is affirmed or denied of an entire class that is denoted by a general term may be affirmed or denied of everything included in that class."

† During the Middle Ages when Aristotelian logic was dominant in the Universities of Europe, the following lines were devised to indicate the valid moods that may occur in each of the four figures and also to indicate the method by which the argument could be reduced to the first figure.

Barbara, Celarent, Darii, Ferioque prioris ;
Cesare, Camestres, Festino, Baroko, secundae ;
Tertia, Darapti, Disamis, Datisi, Felapton,
Bokardo, Ferison, habet ; quanta insuper addit
Bramantip, Camenes, Dimaris, Fesapo, Fresison.

The three vowels in each of the italicized words represents the valid moods that occur for each figure, thus *Barbara* stands for the mood AAA in the first figure ; *Cesare* for the mood EAE of the second figure, etc. There are six moods for the third figure and five for the fourth figure. The letter *S* in *Cesare* indicates that the minor premise should be converted by simple conversion to reduce to the first figure ; the letter *P* in *Darapti* indicated that conversion by limitation or per accidens is necessary ; *K* in *Baroko* indicates that the indirect method should be followed.

As examples of that type of syllogism in which the relations expressed are both symmetrical and transitive we may cite the following:

(1) The value of Book A is equivalent to that of Book B.
The value of Book B is equivalent to that of Book C.
∴ The value of Book A is equivalent to that of Book C.

(2) The line AB is parallel to the line CD.
The line CD is parallel to the line EF.
∴ The line AB is parallel to the line EF.

In dealing with syllogisms of this type there are two rules which apply:

1. When the relation expressed in both premises is symmetrical and transitive, the same relation should be expressed in the conclusion.

2. When the relation expressed in one premise is that of agreement or similarity and the relation expressed in the other premise is that of difference in the same respect, then the relation which expresses difference should be stated in the conclusion.

As an example of that type of syllogism in which the relations expressed are asymmetrical and transitive, we may give the following:

(1) Chicago is east of Omaha.
Omaha is east of Denver.
∴ Chicago is east of Denver.

And in the following example the relations expressed are asymmetrical and intransitive:

(2) John is the father of Henry.
William is the father of John.
∴ William is the grandfather of Henry.

Sorites. A series of syllogistic arguments may be combined in such a way that the conclusion of one syllogism becomes a premise for the next one. As a general rule only the conclusion of the last syllogism in the series is expressed. A chain of reasoning or series of arguments of this kind is known as a sorites. There are two types of sorites known respectively as the Aristotelian and the Goclenian. In the Aristotelian sorites, the subject of the first premise in the series becomes the subject of the conclusion, and the predicate of the last premise becomes the predicate of the conclusion. The following is an example of this type of sorites:

All dictatorships are tyrannical forms of government.
All tyrannical forms of government are oppressive.
All oppressive governments rob the poor.
All governments that rob the poor should be abolished.
∴ All dictatorships should be abolished.

Three syllogistic arguments are implied in this sorites. Should each one be stated in full, we would have the conclusion of the first syllogism for the minor premise of the second syllogism, and the conclusion of the second syllogism would be the minor premise of the third.

There are two rules which apply to this type of sorites.

1. Only the last premise may be negative, all the rest must be affirmative.

2. Only the first premise may be particular, all the rest must be universal.

The violation of the first rule results in the fallacy of illicit major, and the violation of the second rule results in the fallacy of undistributed middle.

In the Goclenian * sorites the predicate of the conclusion is contained in the first premise and the subject of the conclusion is the subject of the last premise. The following is an example.

All natural rights are guaranteed by the state.
All private property is a natural right.
All trade monopolies are cases of private property.
All oil industries are cases of trade monopolies.
∴ All oil industries are guaranteed by the state.

If we expand this sorites into three syllogisms we will have the conclusion of the first syllogism as the major premise of the second one, and the conclusion of the second syllogism as the major premise of the third. The two rules which apply to this type of sorites are:

1. Only the first premise may be negative, all the rest must be affirmative.
2. Only the last premise may be particular, all the rest must be universal.

When the first rule is violated we have the fallacy of illicit major, and when the second one is violated we have the fallacy of undistributed middle.

QUESTIONS AND EXERCISES

1. Name two ways of classifying syllogisms and mention the distinguishing characteristic of each type included under both classifications.
2. Define each of the following: major term, minor term, middle term, major premise, minor premise. How may the conclusion of a syllogism be distinguished from the premises?
3. Mention five rules that are applicable to the categorical syllogism.

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* This type of sorites was first used by Rudolph Goclenius, 1547-1628.

4. Explain briefly the function of the middle term in a categorical syllogism.
5. What is meant by the mood of a categorical syllogism? How is the figure of a syllogism determined? What is the position of the middle term in each of the four figures?
6. What is meant by the reduction of figures? Describe briefly two ways of reducing arguments.
7. Prove, without using the textbook, the rules for each of the four figures.
8. Why is the I E mood impossible in each of the four figures?
9. Why is it that only negative conclusions may be obtained in the 2nd figure, and only particular conclusions in the 3rd?
10. In what figures may the middle term be distributed twice?
11. Put the following arguments into strict syllogistic form. Give the mood and figure, and name the fallacy if any is present.
    (1) Whoever believes this is a radical, but you are not a radical since you do not believe it.
    (2) All disciples of Plato are idealists. And since you are an idealist it follows that you must be a disciple of Plato.
    (3) Only churches have cross-crowned spires. This building has a cross-crowned spire and therefore it is a church.
    (4) All books are human productions, and all books are liable to error. Therefore all human productions are liable to error. (Creighton)
    (5) Since only ignorant people despise knowledge, this man cannot be ignorant, for he praises knowledge.
    (6) Restless nations are not progressive, for all civilized nations are progressive, and no restless nations are civilized.
    (7) Every valid syllogism has three terms. This syllogism has three terms and is therefore valid. (Creighton)
    (8) Some lawyers are Republicans. So are some honest men. Therefore some honest men are lawyers. (Robinson)
    (9) Some useful metals are becoming rarer. Iron is a useful metal, and therefore it is becoming rarer. (Creighton)
    (10) Partisans are not to be trusted. Democrats are partisans, and therefore they should not be trusted. (Creighton)
    (11) Only those messages that are prepaid will be delivered. This message has been prepaid and therefore it will be delivered.
    (12) No pauper has a right to vote. This man is not a pauper and therefore he has a right to vote. (Creighton)

(13) This metal cannot be silver, for it is not soluble in nitric acid, as silver is. (Wolf)

(14) Innocent people ought not to be punished. This man ought not to be punished, and from this I infer that he is innocent.

(15) Charles Dickens was a great novelist. We know this because he wrote many books, and all great novelists do that.

(16) All Socialists favor the interference of government in private industry. Some Democrats favor the same interference on the part of the government; therefore, some Democrats are Socialists.

(17) All those persons who make a high score in the intelligence tests have superior minds. These individuals did not make a high score in their intelligence tests, and, therefore, they do not have superior minds.

(18) All persons who oppose vivisection are persons who love animals. No investigators in physiology are opposed to vivisection. Therefore, no investigators in physiology are persons who love animals. (Clarke)

12. Make a list of relations which are symmetrical. Construct three syllogisms in which these relations are used.
13. Do the same for relations which are asymmetrical.
14. Construct three syllogisms in which the relations expressed are symmetrical and transitive.
15. Do the same for relations which are asymmetrical and intransitive.
16. What is a sorites? Distinguish between the Aristotelian and Goclenian sorites.
17. Why is it that in the Aristotelian sorites all of the premises except the first must be universal?
18. Why is it that in the Goclenian sorites the first premise is the only one that can be negative, and the last one the only one that can be particular?
19. Construct an argument to illustrate the Aristotelian sorites.
20. Construct an argument to illustrate the Goclenian sorites.
21. Select from your reading or conversations with others several examples of valid syllogisms.
22. Make a list of syllogisms to illustrate each of the following fallacies: undistributed middle, illicit major, illicit minor, two negative premises.

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CHAPTER IX

HYPOTHETICAL AND DISJUNCTIVE SYLLOGISMS

As we have noted before, syllogisms may be classified according to the type of proposition used in the major premise. For instance, categorical syllogisms are those in which both the major and the minor premises are categorical propositions. But it is possible for a syllogism to have as its major premise a hypothetical or a disjunctive proposition. In these cases the result will be either a hypothetical syllogism or a disjunctive syllogism. A hypothetical syllogism may then be defined as one in which the major premise is a hypothetical proposition and the minor premise is a categorical proposition. And likewise we may define a disjunctive syllogism as one in which the major premise is a disjunctive proposition and the minor premise is a categorical proposition.

The Hypothetical Syllogism. The following is an example of the hypothetical syllogism:

major premise	If he works hard, he will succeed.
minor premise	He will work hard.
conclusion	Therefore, he will succeed.

The major premise of this syllogism is a hypothetical proposition and as such it is made up of two parts. The first of these is called the *antecedent*, and the second is known as the *consequent*. The antecedent is that part of the proposition which expresses the condition. And the consequent is that part which states the result which follows whenever the condition expressed in the antecedent is fulfilled. Since the hypothetical proposition deals with conditions and the consequences which follow from them instead of expressing the relation of exclusion or inclusion between classes of objects, it does not possess quality and quantity. Neither do we speak of special figures for the hypothetical syllogism.

There are two valid moods for the hypothetical syllogism. These are known as *modus ponens* or the mood which affirms, and *modus tollens* or the mood which denies. The first of these two moods occurs whenever the minor premise affirms the antecedent of the major premise. The following is an example:

If it rains immediately, the drought will be averted.
It will rain immediately.
∴ The drought will be averted.

Whenever a hypothetical syllogism possesses this mood it is called a *constructive* hypothetical syllogism.

The second of these moods, or *modus tollens,* occurs whenever the minor premise denies the consequent of the major premise. The following is an example:

If this object is made of steel, it will be heavy.
The object is not heavy.
∴ It is not made of steel.

Whenever this mood occurs in the hypothetical syllogism the syllogism is called *destructive.* It should be noted, however, that the minor premise is not necessarily affirmative in form in the constructive syllogism, nor is it necessarily negative in the case of the destructive syllogism. For example, in the following case,

If it does not rain immediately, crops will be ruined.
It will not rain immediately.
∴ The crops will be ruined.

the minor premise, though a negative proposition, does affirm the condition which is specified in the antecedent of the major premise. Hence the syllogism is constructive. Again, when the consequent of the major premise is a negative statement, the minor premise may be affirmative in form but because it denies the given consequent, the syllogism will be destructive. This is true in the following example:

If man is not capable of progress, he does not differ from the brutes.
But man does differ from the brutes.
∴ He is capable of progress.

Since there are only two valid moods of the hypothetical syllogism it is an easy matter to formulate the rule which must be observed in the dealing with syllogisms of this type. It is as follows: *Either affirm the antecedent or deny the consequent.* When this rule is violated one or the other of two fallacies will be the result. The first of these fallacies is known as *denying the antecedent.* It may be illustrated by the following example:

If prices continue to rise, the poor will suffer.
Prices will not continue to rise.
∴ The poor will not suffer.

The second of the two fallacies is known as *affirming the consequent,* and may be illustrated by the following:

If a man drinks carbolic acid, he will die.
This man is dead.
∴ He drank carbolic acid.

One exception, however, must be made to the general rule for the hypothetical syllogism. Whenever the antecedent expresses the sole or *essential* condition of the consequent, it is possible to obtain a valid conclusion by denying the antecedent or by affirming the consequent. The following is an example frequently used to illustrate this type of hypothetical syllogism:

If a triangle is equiangular, it is equilateral.
This triangle is not equiangular.
∴ It is not equilateral.

It will be recognized that the major premise in this example is analogous to the categorical A proposition in which the extension of the subject and predicate terms coincide, and in which the predicate term is therefore distributed.

Relation of Hypothetical to Categorical Syllogisms. A categorical proposition which expresses the relation of exclusion or inclusion between two classes of objects does not state all of the meaning which the proposition implies. In our chapter on "Terms" we said that every logical term has both an extensive and an intensive meaning. The extensive meaning refers to the objects to which the term may be applied while the intensive meaning refers to the qualities or attributes of these objects. This distinction may help us to understand the relationship of hypothetical to categorical propositions.

Categorical propositions, in so far as they express the relation of exclusion or inclusion, take into account only the extensive meaning of the terms involved. Hypothetical propositions, on the other hand, deal only with the intensive meaning of the terms. For example, in the categorical proposition "All metals are elements" we are asserting that the class of objects known as "metals" is included in the class of objects known as "elements." Nothing is asserted here concerning the qualities of either metals or elements. But in the hypothetical proposition "If this is a metal, it is an element," the meaning which is expressed is clearly that the qualities or attributes of metals and elements are such that an object cannot belong to the first class without also belonging to the second one. Of course these two meanings are closely related and each one clearly implies the other.

It is for this reason that it is always possible to change a hypothetical proposition into categorical form and vice versa. Propositions of the type with which we have been dealing have, we may say, two meanings, one of which is hypothetical and the other categorical, and it is always possible to go from one of these meanings to the other one.

Now what we have said concerning the relationship of hypothetical and categorical propositions applies in a similar way to these two types of syllogism. And for the reasons which we have just stated it is possible to reduce any hypothetical syllogism to a categorical syllogism. If the argument is valid in the hypothetical form it will also be valid in the categorical form. And, likewise, if it is invalid in one of these forms, it will also be invalid when changed to the other form.

To reduce a hypothetical syllogism to categorical form it is necessary first of all to change the major premise of the hypothetical argument into a categorical proposition. This may be done by making a class term out of the antecedent and using this as the subject term of the proposition. The consequent should then be converted into another class term and used as the predicate term of the proposition. These two terms should then be joined by the copula, and, since the resulting proposition will always be a universal affirmative, the prefix "all" should be used before the subject term and the letter "A" should be placed after the predicate term. Having reduced the major premise of the hypothetical syllogism to a categorical proposition of the universal affirmative type, one needs only to state the minor premise in its logical form. The minor premise should always be stated as either an A or an E proposition. If the minor premise in the hypothetical syllogism affirms the antecedent, then it should be stated as an A proposition, but if in the hypothetical syllogism it denies the consequent, then it should be stated as an E proposition. The following illustrations will help to make this clear. We will consider first an example of *modus ponens.*

If men are thrifty, they will be prosperous.
This man is thrifty.
∴ He will be prosperous.

Reduced to categorical form this argument will appear as follows:

All (thrifty men) are (those who will be prosperous) A.

All (this man) is (a thrifty man) A.
∴ All (this man) is (one who will be prosperous) A.

Mood AAA Figure I

We will consider next an example of *modus tollens.*

If you believe this, you are a heretic.
But you are not a heretic.
∴ You do not believe it.

Reducing this argument to categorical form we have:

All (those who believe this) are (heretics) A.
No (you) are (a heretic) E.
∴ No (you) are (one who believes this) E.

Mood AEE, Figure II

Since both of these examples are valid arguments in their hypothetical form they are also valid when stated in terms of the categorical syllogism. If, however, the hypothetical syllogism contains the fallacy of denying the antecedent, when it is reduced to categorical form the result will be an AEE mood of the first figure and the fallacy of *illicit major.* If the hypothetical syllogism contains the fallacy of affirming the consequent and it is then reduced to categorical form, the result will be an AAA mood of the second figure and the fallacy of *undistributed middle.*

We have said that a valid conclusion may be obtained by denying the antecedent or affirming the consequent provided that the antecedent expresses the sole or essential condition of the consequent. For example:

If it becomes colder, the river will freeze.
But it will not be colder tonight.
∴ The river will not freeze.

When this argument is transferred to categorical form it appears to contain a fallacy, thus:

All (condition of being colder) is (condition of river being frozen) A.
No (tonight) is (condition of being colder) E.
∴ No (tonight) is (condition of river being frozen) E.

Mood AEE, Figure I

As a general rule the mood AEE in the first figure contains the fallacy of illicit major. But that fallacy is not present in this case since the predicate of the major premise is distributed due to the fact that the extension of this term coincides with the extension of the subject term. Hence we may conclude that all valid hypothetical syllogisms can be transferred to categorical form without any fallacy being involved.

The Disjunctive Syllogism. A disjunctive syllogism is that type of argument in which the major premise is a disjunctive proposition and the minor premise is a categorical proposition. A disjunctive proposition is one that contains two alternatives that are so related to each other that when one is affirmed in the minor premise, the other one must be denied in the conclusion, and vice versa. There are two valid moods of the disjunctive syllogism. The first one is known as *modus tollendo ponens.* This is the mood in which the minor premise denies one of the alternatives, and the conclusion affirms the other one. The following is an example:

This man is either a Republican or a Democrat.
He is not a Republican.
∴ He is a Democrat.

The other mood of the disjunctive syllogism is known as *modus ponendo tollens.* This is the mood in which one of the alternatives is affirmed in the minor premise and the other one is denied in the conclusion. The following is an example of this mood:

This tree is either a chestnut or an oak.
It is a chestnut.
∴ It is not an oak.

The validity of the conclusion reached in any disjunctive syllogism depends upon whether there is a perfect disjunction in the major premise. If the two alternatives which occur in that premise are related to each other in such a way that they do not overlap and yet include all of the possible alternatives, then the disjunction is perfect and the validity of the conclusion is well established. The only fallacy which may occur in the disjunctive syllogism is what is known as *imperfect disjunction.* This occurs whenever the two alternatives are not exhaustive or are not mutually exclusive. An example of this fallacy may be seen in the following argument. "Since this boy has not prepared his lesson we may conclude either that he has been sick or that he has been lazy. But we know that he has not been sick, and therefore we may infer that he has been lazy." Obviously the two alternatives "being sick" and "being lazy" as they are employed in this argument are not exhaustive nor are they necessarily mutually exclusive. It is possible that some other factor may be responsible for the boy's lack of preparation and it might be true that he was both lazy and sick. Hence the conclusion cannot under these conditions be said to be valid.

The Alternative Syllogism. Alternative syllogisms include those that are disjunctive. But they also include other forms which may yield valid conclusions even though the alternatives used in the major premise may not be disjunctive. For example, if in relation to some communication you are about to make with another party you say, "Either I will call him by telephone or I will write him a letter," a denial of one of these alternatives will necessarily mean the affirmation of the other one. But it is not true that the affirmation of one of them will necessarily mean a denial of the other one. It is quite possible that you may communicate with the party in question both by telephone and by writing him a letter. Other examples of the alternative syllogism may be seen in the following:

This man is either an American or a Jew;
He is not a Jew:
Therefore, he is an American.

X is either A or **B**;
It is not B:
Therefore, it is A.

The conclusion is valid in each of these examples. But the conclusion would be invalid in either case if an affirmation of one alternative in the minor premise should be followed by a denial of the other alternative in the conclusion. Hence, one should always be on guard with reference to the use of alternative syllogisms in which the minor premise is affirmative. The conclusion can be valid in instances of this kind only when the alternatives used in the major premise are exhaustive and exclusive.

The Dilemma. The dilemma, another type of syllogistic argument, contains both hypothetical and disjunctive propositions. As a general rule the major premise contains two hypothetical propositions and the minor premise is a disjunctive proposition. It is possible, however, for the disjunction to occur in the major premise, in which case that premise will consist of one hypothetical proposition and one disjunctive proposition. The conclusion of a dilemma may be either a categorical proposition or a disjunctive proposition. A dilemma may be further described as that type of argument in which two alternatives are presented with a statement of the consequents which must follow in each case. Since one of the alternatives must be accepted it follows that one or the other of the two consequents must also be accepted. A person who is engaged in a debate may be said to have placed his opponent in a dilemma when he can show that the opponent is confronted with two courses of action one of which must be accepted but both of which are unfavorable to him.

If we wish to define a dilemma in terms of the kinds of propositions which it contains, we may say that it is a *compound hypothetical syllogism* partly disjunctive in form. The alternatives in a dilemmatic argument are usually known as the *horns* of the dilemma, and it is for this reason that the dilemma is sometimes defined as a *horned syllogism.* Since the dilemma is a compound type of argument which includes elements from both the hypothetical and the disjunctive syllogisms, it follows that the rules which govern these two types of syllogisms are also applicable to the dilemma. In other words it is necessary for the proper construction of a dilemmatic argument that, in the case of the hypothetical propositions used, either the antecedents shall be affirmed or the consequents shall be denied; and that in the case of the disjunctive proposition, the two alternatives shall be both exhaustive and mutually exclusive.

Dilemmas may be classified as (1) *simple constructive,* (2) *simple destructive,* (3) *complex constructive,* and (4) *complex destructive.* The simplest way of determining to which one of these four classes any particular dilemma belongs is to examine the conclusion. If the conclusion is a categorical proposition the dilemma is simple, and if the conclusion is a disjunctive proposition the dilemma is complex. Again, if the conclusion is affirmative the dilemma is constructive; and if it is negative the dilemma is destructive. It is also possible to determine the classification of a dilemma by an examination of the premises which it contains. If the antecedents of the two hypothetical propositions are affirmed in the minor premise, then the dilemma will be constructive, while if the two consequents are denied in the minor premise, the dilemma will be destructive. In case the two antecedents affirmed or the two consequents denied are identical, the dilemma will be simple, while if they are not identical the dilemma will be complex. The form of the simple constructive dilemma may be indicated by the following:

If A is B, then C is D; and if E is F, then C is D.
But either A is B or E is F.
∴ C is D.

Or we may indicate the same by means of the following concrete example:

"If I go to war I am likely to be killed by the enemy; and if I refuse to go to war I am likely to be killed as a traitor to my country. But either I must go to war or I must refuse to go to war. Therefore in either case I am likely to be killed."

The simple destructive dilemma may have the following form:

If A is B, then either C is D or E is F.
But we know that C is not D and E is not F.
∴ A is not B.

In this type of dilemma the major premise is made up of a hypothetical and a disjunctive proposition, and the minor premise denies both of the alternatives in the disjunction. The following is a concrete example. "If the figure known as William Tell is a historical character, then either he must have been mentioned by early historians, or his personality must be necessary to explain known facts of history. But he was not mentioned by early historians and his personality is not necessary to explain known facts of history. Therefore, he is not a historical character."

The complex constructive dilemma is one in which neither the antecedents nor the consequents are identical and in which the minor premise affirms disjunctively the two antecedents found in the major premise. The form for this type of dilemma may be indicated as follows:

If A is B, then C is D; and if E is F, then G is H.
But either A is B or E is F.
∴ Either C is D or G is H.

Or we may illustrate this type of dilemma by the following example:

When the famous Alexandrian library was burned by the Mohammedan Turks, the Caliph Omar is said to have presented this argument as a justification for the act: "If these books contain the same doctrines as the Koran they are unnecessary; and if they do not contain the same doctrines as the Koran but are at variance with it, then they are wicked and pernicious. But the books must either contain the same doctrines as the Koran or else be at variance with it. Therefore, the books are either unnecessary or they are wicked and pernicious."

The complex destructive dilemma is also one in which neither the two antecedents nor the two consequents are identical, but it differs from the complex constructive dilemma in that the two consequents are denied disjunctively in the minor premise. The form for this type of dilemma is as follows:

If A is B, then C is D; and if E is F, then G is H.
But either C is not D or G is not H.
∴ Either A is not B or E is not F.

And the following is a concrete example of the same type of argument:

"If a man is honest he will not defraud his neighbor knowingly, and if he is intelligent he will not do it ignorantly. But either he defrauded his neighbor knowingly or he did it ignorantly. Therefore we may conclude that he was either not honest or he was not intelligent."

Fallacies of the Dilemma. A dilemmatic argument may be valid. When based upon premises which are true and when constructed in accordance with the rules which govern correct syllogistic procedure it presents a sound conclusion and is a very effective and convincing form of argumentation. But the dilemma is a rather complex type of argument and it may contain any one of three fallacies. One of these is the fallacy of imperfect disjunction; another one is the use of consequents in the hypothetical propositions which do not follow logically from the antecedents; and the third one consists in the use of two standards of reference for the propositions used in the major premise. The traditional terminology used to indicate these three fallacies is known respectively as the escape between the horns, taking the dilemma by the horns, and the construction of a counter dilemma; the term "horns" referring of course to the alternatives of the disjunction. We will now describe more in detail each one of these fallacies.

(1) One may escape between the horns of a dilemma whenever the alternatives used in the disjunctive proposition are not exhaustive or are not mutually exclusive. The following dilemmatic argument may be successfully attacked in this way:

"If students are determined to develop their mental powers to the best of their ability, they do not need the incentive of academic honors; and if students are lazy and indifferent to mental improvement, it will be useless to offer them. But students are either determined to improve their minds to the best of their ability or they are lazy and indifferent to mental improvement. Therefore, academic honors are either unnecessary or they are useless."

This is a complex constructive dilemma. The conclusion is invalid since the disjunction in the minor premise is not exhaustive. It is true that there are some students who would always do their best work regardless of whether honors were offered them. And it is also true that there are some students for whom the offering of academic honors is not a sufficient incentive to cause them to do good work. But these two classes do not include all students. There is a third group made up of those who will work better when honors are offered them for so doing.

(2) To take a dilemma "by the horns" is to show that in the hypothetical propositions used in the major premise, the consequents do not follow logically from the antecedents. This means virtually that we challenge the validity or truth of the major premise by showing that the assertions which have been made are false. To do this will mean, in the majority of cases at least, that we go outside the sphere of logic and deal with the subject matter from which the

premises have been derived. But there are some cases in which the self-contradictory nature of the premises can be pointed out without leaving the proper sphere of logic. A case in point is the much quoted argument of Zeno concerning the impossibility of motion. The argument may be stated as a simple destructive dilemma, and we may take it "by the horns." It is as follows:

"If a thing moves, it must move either in the place where it is or in the place where it is not. But it cannot move where it is and it cannot move where it is not. Therefore it cannot move."

(3) The third way of attacking a dilemmatic argument is to construct a counter-dilemma. This means that we construct another dilemma similar in form to the original one but leading to an opposite conclusion. Obviously the reasoning involved in both the original dilemma and the counter-dilemma is fallacious, the same type of fallacy being present in the one case as in the other. Nevertheless the construction of a counter-dilemma is an effective means of showing up the fallacy which was present in the original argument. A good example of a dilemma which may be attacked in this way is the argument between the Greek Sophist, Protagoras, and his pupil. Protagoras, who always charged a fee for private instruction, had been approached by a pupil who wanted to learn how to handle cases in court, but he did not have any money to pay for his instruction. However, Protagoras agreed to give him the desired instruction on condition that the pupil would pay him as soon as he had won his first case at court. The pupil received the instruction but did not begin to practice his newly acquired art, and thus Protagoras was out his fee. He then brought suit against his pupil and reasoned as follows:

"If I win this case, then he will have to pay me in accordance with the decision of the court; and if he wins the case he will have to pay me in accordance with the terms of the contract. But either I will win this case, or he will win it. Therefore, in either case he will have to pay me."

But in reply to this argument the pupil presented the following counter-dilemma:

"If I win the case I will not have to pay in accordance with the decision of the court, and if he wins the case I will not have to pay according to the terms of the contract. But either I will win the case or he will win it. Therefore, in either case I will not have to pay."

We see in this case that the reasoning which the pupil presents in the counter-dilemma is of the same type as that used by Protagoras, and though it leads to the opposite conclusion, the argument is as strong in one case as it is in the other. The fallacy, however, which is present in both cases is that of two standards of reference. In each dilemma we find that *the decision of the court* is the standard used in one hypothetical proposition but *the terms of the contract* is the standard used for the other one. In neither case would it be possible for both hypothetical propositions to be true when judged by the same standard. This method of attacking a dilemma can be used successfully only when there are two standards of reference used in the major premise.

In order to construct a counter-dilemma it is necessary (1) to take the contradictory of the second consequent and affirm it of the first antecedent, and (2) to take the contradictory of the first consequent and affirm it of the second antecedent. The minor premise will be the same as in the original dilemma, and the conclusion will be the opposite of the original.

QUESTIONS AND EXERCISES

1. What is the difference in meaning between the two following propositions: "All men are mortal" and "If he is a man, then he is a mortal"? What meanings are always emphasized by the categorical and hypothetical propositions respectively?
2. What are the two elements of a hypothetical proposition? Name and illustrate each of the two valid moods of the hypothetical syllogism.

3. Name two fallacies of the hypothetical syllogism. Construct arguments to illustrate each of these. Transfer each of these arguments to categorical form and indicate the fallacy which results.
4. Under what condition is it possible to obtain a valid conclusion by denying the antecedent or affirming the consequent? Construct an argument in which this condition is fulfilled.
5. What procedure should be followed in changing an argument from hypothetical to categorical form? To what categorical fallacy does the fallacy of denying the antecedent correspond? the fallacy of affirming the consequent?
6. Criticize the following hypothetical syllogisms stating whether or not each one is valid. Transfer each argument to categorical form, give the mood and figure and name the fallacy if any be present.
    (1) If a man is innocent, he should not be punished. This man should not be punished and, therefore, he is innocent.
    (2) If a man does not believe the Bible, he is unorthodox. But since you do believe the Bible, it follows that you are orthodox.
    (3) If the government is just, the rights of no one will be exploited. But under the present government the rights of some people are exploited. Therefore, the present government is not a just one.
    (4) If the astronomer's predictions are fulfilled the correctness of his reasoning is thereby established. The predictions in this case have been fulfilled and therefore his reasoning is shown to be correct.
    (5) If a man drinks carbolic acid he will die. This man is found dead. Therefore, he drank carbolic acid.
    (6) If it is an acid it will turn blue litmus paper red. This substance turns blue litmus paper red. Therefore, it is an acid.
    (7) If capitalism can be modified the present order will remain. But we know that capitalism cannot be modified; therefore the present order will not remain.
    (8) If the philosophy of mechanism be true, there can be no such thing as a moral obligation. But we can experience moral obligation directly. Therefore, the philosophy of mechanism is not true.
7. Name the two valid moods of the disjunctive syllogism. Construct arguments to illustrate each.

8. What fallacy may occur in the disjunctive syllogism? Construct an argument in which this fallacy is present.
9. What is an alternative syllogism? How does it differ from the disjunctive syllogism? Give an example. When are alternative syllogisms invalid?
10. Criticize the following disjunctive arguments; give the mood in each case, and indicate which ones are valid and which ones are invalid:
    (1) The cause of this epidemic is either an impure water supply or an impure milk supply. But we know that the water supply has been kept free of any contaminating material. Therefore, the cause must be an impure milk supply.
    (2) Either this man is careless or he is ignorant. But since we know that he was putting forth his best efforts, he must have been ignorant.
    (3) Christianity and the war system do not belong together. It is either Christ or war. Therefore, those who support the war system are not Christians.
    (4) Our ideas must be either the product of our experience or else be innate. But since we can prove that none of our ideas are innate it must be that they are the product of our experience.
    (5) Since A does not have his lesson we may infer that he was either lazy or he has been sick. But since we know that he was sick we may conclude that he has not been lazy.
11. What is a dilemma? Why is it sometimes called a "compound hypothetical syllogism"? a "horned" syllogism?
12. What are the four types or classes of dilemma? What is the distinguishing characteristic in each case?
13. Construct a dilemmatic argument to illustrate each of the four kinds. (Do not use examples given in the text.)
14. Describe each of the three ways of attacking a dilemma and tell when each one is applicable.
15. What method of procedure should be followed in the construction of a counter-dilemma?
16. Construct a dilemmatic argument in which it is possible to "escape between the horns"; to take it "by the horns."
17. Construct one in which there are two standards of reference, and then construct the counter dilemma.

18. From your general readings and conversations make a short list of dilemmatic arguments.
19. Make a similar list of alternative syllogisms. Make a logical criticism of each one.

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CHAPTER X

FALLACIES OF DEDUCTIVE REASONING

A FALLACY is an error in reasoning. Some particular fallacy is present whenever any of the rules or principles of correct thinking have been violated. It is not within the province of logic to deal exhaustively with all the types of error to which the human mind is subject. It is doubtful whether a complete list of these errors could ever be made by any one person. At any rate logic has to do with only a part of them.

It is possible to reach conclusions which are false without violating any of the rules of logic. For example, many of the erroneous conclusions which have been reached in the history of human thinking have been due to false premises rather than failure to observe the rules of logic in drawing inferences from them. Others have been due to such factors as inaccurate observations, failure to take into account all of the relevant facts, neglect of negative instances, the predominance of emotional over rational factors, and many other causes.

The discussion of deductive fallacies has to do only with those errors that occur in drawing inferences from premises that have already been given. Even within this limited field it is quite impossible to present an exhaustive list of the fallacies which may occur. It is the purpose of this present chapter to deal briefly with only the more common errors which have to do with deductive reasoning. Some of these fallacies have already been presented in connection with the discussions of the immediate inferences and the rules for the various types of syllogisms. But in addition to these there are many other fallacies that so far have not been mentioned and it is to these that we now give our attention.

In Chapter I it was stated, in connection with the discussion of the definition and purpose of logic, that this field of knowledge is sometimes considered an art as well as a science. There are some good reasons for this even though it is true that logic belongs more to the sciences than it does to the arts. In so far as it is an art, it is really the art of detecting fallacies. It is in connection with the practice of this art that we recognize one of the chief values of a study of the fallacies. To be able to detect any and all of the mistakes which people make in their reasonings is no easy task. It is one in which even the best logicians do not achieve perfection. But it does help a great deal if one can name the more common fallacies, define each one with precision and tell where it is most likely to occur.

Before taking up the particular fallacies with which we are concerned in this chapter it may be well to point out a distinction between the term "fallacy" and two other terms which are sometimes used interchangeably with it. These are *sophism* and *paralogism*. A sophism is an erroneous type of argument that is used deliberately for the purpose of winning a case. Aristotle discusses at length this particular device which was used frequently by the Greek rhetoricians. Its purpose was not the presentation of truth, though it often proved an effective means of convincing an audience. A paralogism differs from a sophism in that it is not a deliberate attempt to deceive on the part of the one who uses it. The fallacy is due rather to an ambiguity in the meaning of the words that are used. Both sophism and paralogism are included in the term fallacy, but there are other fallacies than those to which these two terms may be applied.

The study of fallacies is not of course directly a part of the science of logic. A knowledge of the rules or principles of correct thinking does not include (except by way of contrast) a statement of the various ways in which these principles may be violated. Nevertheless contrast is often a very effective method of learning. Some familiarity with the way in which the rules of logic are frequently violated will be an aid toward fixing these rules definitely in one's mind.

Fallacies may be classified in several different ways. For our purpose it will be most convenient to divide them into two classes; (A) those that have to do with the immediate references, and (B) those that have to do with the mediate inferences. Class B will then be subdivided into two groups. (1) formal fallacies, and (2) material fallacies. And finally the material fallacies will be divided into (a) fallacies of equivocation, and (b) fallacies of presumption. The following device will serve as a useful classification of the more common fallacies.

A. Fallacies that have to do with the immediate inferences
  1. Violation of the rules for the immediate inferences
  2. Verbal Fallacies
    (a) Accent
    (b) Amphiboly
B. Fallacies that have to do with the mediate inferences
  1. Formal fallacies
    (a) Categorical syllogism
      (1) Four terms
      (2) Two negatives
      (3) Illicit major or minor
      (4) Undistributed middle
    (b) Hypothetical syllogism
      (1) Denying the antecedent
      (2) Affirming the consequent
    (c) Disjunctive syllogism
      (1) Imperfect disjunction
    (d) The dilemma
      (1) Imperfect disjunction (escape between the horns)
      (2) Consequents do not follow antecedents (by the horns)
      (3) Two standards of reference (counter-dilemma)
  2. Material Fallacies
    (a) Fallacies of equivocation
      (1) Shifting terms
      (2) Direct accident
      (3) Converse accident
      (4) Composition
      (5) Division

- (b) Fallacies of presumption
    - (1) Petitio principii
    - (2) Irrelevant conclusion
    - (3) Non sequitur

A. *Fallacies of the immediate inferences*

1. The rules which govern the immediate inferences were discussed at length in Chapter VII and need not be repeated here. Perhaps the most common of the fallacies which belong to this group are *illogical obversion* and *illogical conversion.* For example, "Honesty is the best policy" therefore "All dishonesty is bad policy" is a case of illogical obversion. The correct obverse is always obtained by changing the quality of the proposition and by changing the predicate term to its logical contradictory, but in the example given the subject term was changed. Another example of the same fallacy may be seen in the following: "All men are rightfully entitled to the produce of their own labor; therefore, no men are rightfully entitled to anything not the produce of their own labor." (Creighton modified.) In this case the fallacy is not detected so easily. The quality of the proposition has been changed and the predicate term has also been changed. But the predicate term was not changed to the logical contradictory of the original term, hence the fallacy. The most frequent example of illogical conversion consists in the use of simple conversions in cases where conversion by limitation ought to be used. "Virtue is happiness," therefore "Happiness is virtue" is a case in point. And the same is true of "Good citizens are those who obey the laws of their country," therefore "Those who obey the laws of their country are good citizens."

2. *Verbal fallacies* are due not to the violation of rules for the immediate inferences but rather to the presence of ambiguity in the case of the words and sentences that are employed. One of these is known as the fallacy of *accent.* It consists of a change in the meaning of a given proposition by shifting the accent from one word to another. It is remarkable how many different meanings may be derived from

a single proposition by accenting different words. Take for example the proposition "Logic is not supposed to communicate the knowledge of many useless facts" and place the emphasis upon each one of the following words: *logic*, *supposed*, *communicate*, *knowledge*, *many*, and *useless*. A different meaning of the proposition will be obtained in each case. A similar procedure may be followed with reference to the statement taken from the account of the Lord's Supper in the New Testament "Drink ye all of it."

A person who is debating some issue may quote the exact words used by his opponent and yet by changing the accent or the word emphasized make the words mean something other than their author intended. The fallacy of *amphiboly* consists in the use of a proposition that is capable of being interpreted in either of two different ways. An example frequently quoted in logic text books is "I hope that you the enemy will slay." Obviously this may be interpreted to mean that you will slay the enemy or that the enemy will slay you. Another example may be seen in the case of an inscription taken from a tomb-stone "Sacred to the memory of ————, After living with her husband for fifty-five years, she departed in the hope of a better life."

B. *Fallacies of the mediate inferences.*

1. *Formal fallacies* are those which result from a violation of the rules of the syllogism. Since these fallacies were discussed at length in Chapters VIII and IX, nothing further will be said concerning them in this chapter.

2. *Material fallacies* are not due to the violation of rules of the syllogism. The error in this class of fallacies is due either to ambiguity or to the use of material which is irrelevant so far as the issue to be proved is concerned.

(a) *Fallacies of equivocation* which are due to ambiguity are:

(1) The fallacy of *shifting terms*. It consists in the use of a term which has two meanings, one of which is employed in one part of the argument and the other one in another part. Frequently it is the middle term in a cate-

gorical syllogism that is so used. The following will serve as an example. "The end of a thing is its perfection; death is the end of life, and therefore its perfection." The middle term in this syllogism is "end," but in the major premise it means a goal toward which one strives while in the minor premise it means cessation. Again in the example, "All able men are consistent with themselves. Anyone who changes his mind is not consistent with himself; therefore anyone who changes his mind is not an able man," the term "consistent" has two meanings. In one case it means agreement with what one believes to be right but in the other case it means agreement with his former opinions. The term "right" may be used in such a way as to imply a moral right in one case and a legal right in another. This is what occurs in the following example: "What is right for me to do I ought to do. I have a right to vote a straight party ticket at the coming election, therefore I ought to cast my vote in that manner." It should be noted that it is not necessarily the middle term of a categorical syllogism that is used ambiguously. Either the major or the minor term may also be used in the same way. The following argument taken from Mill's essay on Utilitarianism will serve as an illustration: "The only proof we need that a thing is visible is that people see it; the only proof we need that a thing is audible is that people hear it; therefore the only proof we need that a thing is desirable is that people actually desire it." The word "desire" is here used in a double sense, having reference in the first case to that which people ought to have, but in the second case to anything which they wish to have. This fallacy is sometimes known as "Figure of Speech," but for the purpose of avoiding confusion we will regard it as a special case of shifting terms.

(2) The fallacy of *direct accident* is applicable to that type of argument in which the assertion is made that something is true under extraordinary circumstances because it is generally true. Universal employment is under ordinary conditions a sign of industrial prosperity. The Federal Emergency Act makes it possible in many communities for everyone to have work. To conclude that universal employ-

ment under these conditions is an indication of prosperity is an illustration of this fallacy. Another example of direct accident may be seen in the argument that since dictatorial powers in the hands of the ruler of a country is generally detrimental to the welfare of the people, it is therefore undesirable for a ruler to have these powers in times of a great national emergency. And again the argument that the use of drugs by a competent physician should be prohibited because it is not safe for people in general to use them is a further illustration of this fallacy.

(3) *Converse accident* is similar to direct accident in that both fallacies have to do with general cases and extraordinary cases. But in converse accident the assertion is made that something is generally true because it is true under unusual or extraordinary conditions. An example of this fallacy may be seen in the following: "Government ownership of railroads in the United States during the World War was unsuccessful from the point of view of economy and efficiency. Therefore government ownership of railroads under ordinary conditions will be unsuccessful." Again the argument may be advanced that since eminent men such as Abraham Lincoln, Thomas Edison, and Henry Ford did not have a college education and yet were very successful in their respective lines of work, therefore, a college education is unessential for people in general. The fact is that these men were extraordinary persons and hence their success without a college education does not warrant the conclusion that people in general could do the same thing.

(4) The fallacy of *composition* has to do with a whole and the parts that go to make up that whole. It consists in affirming that something which is true of one or more parts when taken separately or distributively is also true of all the parts when taken together or collectively. A simple illustration will serve to make clear the nature of this fallacy. We may argue, for example, that because each one of the articles in this room is worth less than one dollar, therefore all of the articles taken together are worth less than one dollar. Obviously this conclusion is not true and the argument would deceive no one. But it is not always so easy to detect

this fallacy. One of the reasons for this is that our English word "all" has two meanings. Sometimes it is used to refer to each one separately and at other times to a group when considered as a whole. Hence, the shift from one of these meanings to the other one may easily escape detection. The following argument concerning a national recovery program is a good illustration of the fallacy of composition. "One part of this program is of great benefit to the farmers; another part is an aid to the manufacturing businesses; a third part benefits the retail merchants; still another part helps the laboring class; and so on for all the various groups in the country. Therefore the recovery program as a whole will be of great benefit to the entire country."

(5) The fallacy of *division* is just the reverse of composition. It consists in affirming that something is true of one or more of the parts taken separately because it is true of all of them taken together or collectively. For example, "All of the students present in the room constitute the class in logic. Mr. A. is one of the students present in the room; therefore he is the class in logic." "He must be guilty because he was a member of the mob that committed the deed," and "He must be in favor of this particular measure for he belongs to the political party that has endorsed it" are likewise examples of the fallacy of division. To avoid confusion between the two fallacies of accident, and composition and division it should be remembered that the fallacies of accident have to do with general and extraordinary cases whereas composition and division have to do with the parts considered separately and the parts taken as a whole.

(b) *Fallacies of Presumption* are sometimes called fallacies of relevance since they have to do with material which is not relevant so far as the proof for the point at issue is concerned. This group of fallacies includes what is known as "begging the question," or petitio principii, several forms of irrelevant conclusion and non sequitur.

(1) *Petitio Principii* is the fallacy which occurs in that type of argument in which the thing to be proved is assumed in one of the premises. There are several ways in

which this may be done. One of them is to state a proposition in two different ways, using one statement as a premise and the other one as a conclusion. For example I may argue that "this governmental policy should be adopted since it is in harmony with the best interests of the people." Obviously each one of these two statements implies the other one and hence there is no genuine inference in passing from the one to the other. Or, again, I may try to prove that the volume of a body diminishes when it is cooled, offering as a premise the statement that under this condition the parts that go to make up the body will be drawn closer together. "A miracle is incredible since it contradicts the laws of nature" is another example.

A second way of committing the fallacy of petitio or begging the question is to assume, as one of the premises in an argument, a proposition which though not identical in meaning with the conclusion is large enough to include it. An illustration of this may be seen in the argument "Souls do not exist since they are not revealed by even the most powerful microscopes." The thing to be proved in this case is that souls do not exist. To establish this point it is assumed without any proof that whatever does exist is capable of being seen if one uses a powerful microscope. But to grant the truth of that proposition is to grant everything that is contained in the conclusion. Or, as a further example, I may argue that I ought to follow my conscience with reference to some particular matter, since the voice of conscience is something that should be obeyed under any and all conditions.

As a third form of petitio we may mention the fallacy of the *complex question.* This is the interrogative form of begging the question. It occurs in those instances in which the question which one asks is stated in a manner which clearly implies the answer that is desired. For example the question "Why do you prefer to live in the country rather than in the city?" implies that the person addressed does possess that particular preference. "Are you lying to defend yourself or to shield someone other than yourself?" implies that the person is lying and that he is doing it for one or the other of the two purposes mentioned. Lawyers frequently make use of the complex question in their examination of witnesses. If the witness is required to answer the questions put to him by saying either "yes" or "no," it is often an easy matter to state the question so that either one of these two answers will imply that which the witness would be unwilling to admit. As an example, consider this question, "Have you stopped beating your wife?"

The fallacy of petitio principii has sometimes been confused with the legitimate use of the syllogism. For instance, the English logician John Stuart Mill charged that every syllogistic argument is an example of begging the question. In support of that position he called attention to the fact that there is never anything new in the premises. From the two premises *All men are mortal* and *Socrates is a man*, we may indeed draw the conclusion that Socrates is a mortal. But, according to Mill, this is not a genuine inference since the conclusion is already contained in the major premise. In answer to this argument we may admit with Mill that all genuine inferences must present something that is new, or in other words, they must contain something other than a restatement of the premises. But contrary to Mill, we insist that the conclusion in the above example does express something that is new. It is not identical in meaning with either one of the two premises, nor is it contained in either one of them taken by itself. It is only *when the two premises are taken together* that they can be said to contain the conclusion. And when the two premises are considered in that way, there is brought to light another proposition which, though warranted by the two premises, is distinct in meaning from either one of them.

(2) *Irrelevant Conclusion* or Ignoratio Elenchi, as it is sometimes called, is another one of the fallacies of relevance. It consists of that type of argument in which the real point at issue is ignored or set aside and in its place there is substituted some other proposition which has no bearing on the particular point to be proved. This type of argument is

sometimes used intentionally by those who wish to cloud the issue so that the real merits of the argument will not be brought to light. But there are other cases in which it is used unintentionally, due to some confusion with reference to the meaning of the point at issue or to failure to distinguish between propositions which are relevant and those that are not. There are several forms of irrelevant conclusion. They are usually known by Latin names which should be memorized in order that one may recognize the frequent references made to them in current literature. They are as follows:

(a) *Argumentum ad hominem* or argument which concerns the man who is talking rather than the point at issue. For example it may be pointed out that a certain person's argument should be rejected since it can be proved that he has previously supported the opposite side of the question. Or we may try to defend some one against a specific charge by talking about some fine things that he has done in connection with something else. This is well illustrated in the charge which Macaulay made against the defenders of Charles the First: "We charge him with having broken his coronation oath, and we are told that he kept his marriage vow! We accuse him of having given up his people to the merciless inflictions of the most hot-headed and hard-hearted of prelates, and the defense is that he took his little son on his knee and kissed him!" (Quoted from Creighton.) To brand an argument as false because the one who presents it possesses a vicious character is another example of this fallacy. A special case of argumentum ad hominem that is sometimes known as the *tu quoque* form of argument may be seen in the following example: "This man's argument against authoritarianism in religion should be rejected because he accepts a standard in the field of science that is equally authoritarian."

(b) *Argumentum ad populum* is an appeal to the passions and feelings of people in general by a departure from the main point at issue and a substitution of something more or less related to it. A legislator may, for example, in order to get some particular measure passed, talk at length on matters which are irrelevant so far as the measure at hand is concerned but which are nevertheless pleasing to his hearers and which for this reason may aid in securing for him their support. What is known as *argumentum ad misercordiam* is really a special kind of argumentum ad populum. It consists of an appeal to the feelings of pity and sympathy and is well illustrated in the case of the attorney who pleads that his client may be acquitted since the pronouncement of guilt will bring great anguish and suffering to the members of his family.

(c) *Argumentum ad ignorantiam* is the attempt to establish the truth of some particular proposition by dwelling upon the impossibility of proving the opposite. "The souls of human beings survive death because scientists have never been able to present any proof that they do not survive" is an example. And the same is true of the following: "It is impossible to present any evidence which will prove conclusively that criminal traits are not inherited; and we may therefore accept the doctrine that these traits are inherited as a well established principle."

(d) *Argumentum ad vericundiam* is an attempt to settle the point at issue by an appeal to some well established authority. For one to argue that the earth is flat since there are passages of Scripture which support this belief is an example of this fallacy. Or again one may try to establish an argument in support of isolation as a national policy by appealing to the statements of George Washington concerning the dangers of entangling alliances. Or again the argument that "a theistic conception of the universe must represent the truth since it is supported by such eminent scientists as Eddington, Jeans, and Millikan" is another example of the same fallacy. One would not, however, be guilty of this fallacy if in support of a particular doctrine he should refer to the opinion of someone who is a recognized authority *in that field*. Only in cases of that kind it must be understood that the appeal is made to the reasons which the so-called authority gives in support of his view and not to any arbitrary statement of belief which cannot be defended on rational grounds. If, for example, I am dealing with some problem in the field of astronomy, and not being an expert in that field I quote in support of my position some well-known authority on that subject, I am not committing a fallacy. I am merely accepting the reasons which the astronomer whom I have quoted has given. My appeal is to his reasoning rather than to my own; but it is nevertheless an appeal to reason. Anything other than an appeal of this sort would of course illustrate the fallacy of ad vercicundiam.

(3) A third type of the fallacies of relevance which is somewhat similar to the one just discussed is known as *non sequitur*. It refers to that type of argument in which a conclusion that is relevant to the point at issue is drawn from premises that are not relevant so far as the matter of necessary proof is concerned. In the fallacies of irrelevant conclusion the point at issue is set aside, but this is not true in the case of non sequitur. In the latter it is only the premises that are irrelevant. The conclusion has to do with the point under discussion but it is drawn from premises that do not support it. "The theory of evolution is untenable since many of the arguments used in support of it have been shown to be unsound" is a good example of this fallacy. Another example may be seen in the following: "Communism is the best form of government since it can be shown that all other forms have failed in promoting the highest human welfare."

QUESTIONS AND EXERCISES

1. What is a fallacy? Is it possible for a fallacious argument to have a conclusion which is true? For an argument that is not fallacious to have a conclusion which is false? Explain.
2. Explain the statement that logic is the art of detecting fallacies. In what sense is logic to be regarded as a science rather than an art?
3. What is meant by "sophism" and "paralogism"? What justification can be given for including a chapter on fallacies in a text book of logic?

4. How are formal and material fallacies to be distinguished? fallacies of equivocation and fallacies of presumption?
5. Define and illustrate the fallacies of "accent" and "amphiboly." Do the same with "illogical conversion" and "illogical obversion."
6. What is meant by the fallacy of "shifting terms"? Give two examples from outside the text. What distinction is sometimes made between this fallacy and "figure of speech"?
7. Why are the two fallacies of "accident" so often confused with "composition" and "division"? How should they be distinguished?
8. Define and illustrate each of the following: direct accident, converse accident, composition, and division.
9. Why are the "fallacies of presumption" sometimes called "fallacies of relevance"? What is the fallacy of begging the question? What are some of the different ways in which this fallacy may be committed?
10. Explain and illustrate what is known as complex question.
11. How would you answer the charge made by John Stuart Mill that every syllogism is an example of begging the question?
12. How are the fallacies of irrelevant conclusion and non sequitur to be distinguished?
13. Give examples of argumentum ad hominem and argumentum ad ignorantiam.
14. What is meant by argumentum ad misercordiam and how is it related to argumentum ad populum?
15. Explain the legitimate use of an "authority." Show how it differs from an argumentum ad vericundiam.
16. Examine each of the following arguments and determine which ones are valid. In the case of all invalid arguments name the fallacy that is present and give a full statement of your reasons for the criticism which you make.
    (1) It is useless and foolish to state that a college diploma does not signify an education, for a college diploma is awarded only to those who have been educated.
    (2) This argument is in harmony with the teachings of the Bible and therefore it is true.
    (3) If Aristotle is to be regarded as infallible, then logic must be considered an essential part of a liberal education. But since Aristotle is not to be regarded as infallible, it does not follow that logic is essential to a liberal education.

(4) A resolution favoring the enforcement of a prohibition law has been passed by the national federation of women's clubs. As there are two million women in these clubs, we may conclude that all of these persons have endorsed it. (Robinson)

(5) A college education is useless since Henry Ford, Thomas Edison, and Abraham Lincoln succeeded without it.

(6) He who thrusts a knife into another person should be punished; a surgeon in operating does so; hence he should be punished. (Burtt)

(7) A protective tariff is either useless or it is injurious; for it must either produce scarcity or not produce scarcity. If it produces scarcity it is injurious, and if it does not do so it is useless. (Creighton)

(8) Any student in college would stand higher in his class if he received higher marks; hence if all marks were raised ten percent every one would stand nearer the head of his class.

(9) Environmental factors do not produce criminal tendencies since it can be shown that there is a negligible correlation between criminal traits and any one of the so-called environmental factors.

(10) A tomb-stone in the old burying ground at Concord bears the following inscription, "Sacred to the memory of ———, After living with her husband for twenty-five years she departed in the hope of a better life."

(11) There is no single course of study offered by the university of which it may truly be said that it is indispensable for a liberal education. Therefore, one may achieve a liberal education without attending the university at all.

(12) If I understand the author of this book, he is confused in his thinking; and if I do not understand him he is confused in his writing. But since I either understand it or do not understand it, he is confused in his thinking or confused in his writing.

(13) Able men are consistent with themselves. But he who changes his opinions is not consistent with himself. Therefore, he who changes his opinions is not an able man.

(14) Those who give to the poor are really seeking their own pleasure rather than that of others, for if they

did not think they would be happier as a result of their giving they would not do it.

(15) That the human soul survives death is proved by the fact that science is unable to advance any argument which shows conclusively that it does not survive.

(16) What fallacy is charged to the defenders of Charles the first by Macaulay in the following: "We charge him with having broken his coronation oath and the defense is that he kept his marriage vow! We accuse him of having given up his people to the merciless inflictions of the most hot-headed and hard-hearted of prelates and the defense is that he took his little son on his knee and kissed him." (Creighton)

(17) Berkeley maintained that matter does not exist. He insisted that the only things of which we are ever conscious are those things which exist in our minds and hence that outside of mind nothing exists.

(18) Reid replied that Berkeley's theory was absurd since one could not stomp his foot on the ground without experiencing the resistance of matter.

(19) There can be no freedom of the will for every action is the outcome of motives and the stronger motive always wins.

(20) Whatever encourages the reading of books encourages the buying of books. Public libraries encourage the reading of books and therefore they encourage the buying of books. (Creighton)

(21) Your arguments against Mr. A. are of no value since you uphold the beliefs of Mr. B. which are equally repugnant to common sense.

(22) Every book is liable to error. Every book is a human production; therefore every human production is liable to error.

(23) No scientific explanation has ever been given for miracles, and therefore their existence should not be granted.

(24) Logic and mathematics are both formal disciplines. Therefore we may regard the latter as a branch of the former. (Creighton)

(25) If a thing moves it must move either in the place where it is or in the place where it is not. It cannot move in the place where it is and it cannot move in the place where it is not; therefore it cannot move.

(26) This man's arguments should not be accepted, for two years ago he advocated the very measure which he now opposes.

(27) Only those messages which are prepaid will be delivered. This message has been prepaid and will therefore be delivered.

(28) Absence of unemployment is a sign of industrial prosperity. The FERA tends to decrease unemployment and is therefore a sign of prosperity.

(29) If I live for myself, neglecting others, I will be unhappy; and if I live for others, neglecting myself, I will be unhappy. But I must live either for myself or for others, therefore in either case I will be unhappy.

(30) What is right for me to do I ought to do. I have a right to be President of the U. S. and therefore I ought to be elected to that office.

(31) No one should doubt the existence of God since his existence is affirmed by such eminent scientists as Eddington, Millikan, and Einstein.

(32) You say he is *dumb;* but silence gives consent; hence he confesses his guilt.

(33) Mechanism as a philosophy of life is not true since many of the arguments used in support of it have been shown to be false.

(34) The inquisition must have been justified and beneficial if whole peoples invoked and defended it; if men of the loftiest souls founded and created it severally and impartially and its very adversaries applied it on their own account.

(35) It is desirable to reduce the number of deaths from poisoning. Prohibition of the sale of poisons would have this effect and is therefore desirable.

(36) Dogmatic teaching does not make thinking pupils, for it does not encourage independent thinking.

(37) By faith we may believe that those who are known as dead are in reality still alive, for faith is a means of believing that which we know not to be true.

(38) Only the fit survive, and since this organism survived it must have been fit.

(39) A one-house legislature is not likely to be successful, for such eminent men as Wilson, Hamilton, and Jefferson have advocated the two-house system.

(40) The soul does not exist since psychologists armed with high-powered microscopes have not been able to see it.

(41) The theory of evolution is not true, for it was not accepted by Agassiz or Gladstone ; moreover you cannot accept this doctrine, for it is disclaimed by the authorities of your church. (Creighton)

(42) The end of a thing is its perfection ; death is the end of life ; therefore it is its perfection.

(43) It would be greatly to our advantage as a people were we to have a silver standard, for the prosperity of the people would be increased.

(44) The combination which has been formed need not be feared, for all of its members are exceedingly weak and inexperienced.

(45) No punishment should be allowed for the sake of the good that may come from it ; for all punishment is evil and we are not justified in doing evil that good may come from it. (Creighton)

(46) If a man be rightfully entitled to the product of his own labor, then no one can be rightfully entitled to anything that is not the product of his own labor. (Creighton)

(47) The impossibility of proving the non-existence of God discloses that existence to me.

(48) He who calls you a man speaks truly ; he who calls you a fool calls you a man ; therefore he who calls you a fool speaks truly.

(49) I will not do this act because it is unjust ; I know that it is unjust because my conscience tells me so, and my conscience tells me so because the act is wrong. (Creighton)

(50) England has a gold coinage act and is a very wealthy country, therefore it may be inferred that other countries having a gold coinage will be wealthy.

(51) Why advocate socialism ? Until men become morally perfect, it is impossible ; when they have become so, it will be unnecessary.

(52) The governor of a country ought not to be blamed for using his influence to further his religious views, for every man has a right to inculcate his own opinions.

(53) What fallacies do you find in the following argument ? Ghosts exist, because all people in all ages have had faith

in their existence. We know little of our souls even when they animate our bodies and those of our friends. How, then, can we say they may not become ghosts after death? Besides there are kindly ghosts as well as evil-minded ones. It will be an incentive to virtue if we know that the souls of our departed dear ones will, in the form of ghosts, hover about us to watch, guide, and protect us. (Creighton)

17. From your reading of newspapers, magazines, attendance at lectures, etc., make a list of arguments to illustrate each of the following fallacies: petitio principii, division, direct accident, composition, shifting terms, argumentum ad vericundiam, converse accident, argumentum ad hominem, complex question, non sequitur, and argumentum ad ignorantiam.

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PART THREE

SCIENTIFIC VERIFICATION

CHAPTER XI

REASONING FROM PARTICULAR INSTANCES

Observation and Experiment. An analysis of the way in which problems are solved in any of the physical or social sciences is sufficient to show the importance for the reasoning process of a careful observation of particular instances. It is only by taking into account the relevant facts of a given situation that one can properly understand the problem that is before him or formulate intelligently any hypothesis for its solution. And after one has developed by deductive reasoning the implications of an hypothesis, it is only by observing more facts that he can finally determine whether or not his reasoning has led to the correct solution of his problem. Hence it is true, at least from one point of view, that the observation of particular instances is both the beginning and the end of the reasoning process.

The importance of observing facts or particular instances as a means of arriving at the truth concerning the world of nature was greatly emphasized by Francis Bacon in his famous *Novum Organon*, which he wrote to take the place of the older or Aristotelian logic. He criticized the deductive method, which had been used almost exclusively during the Middle Ages, by saying that those who used it were imitating the method of the spider; that is, they were spinning their web out of their own minds. He proposed, in contrast with this, that men should follow the method of the honey-bee, or in other words, gather their store of knowledge from the outside world. It was his deep conviction that the cause of learning would be advanced only after men had ceased to spin theories out of their own minds and had learned to go to the great book of Nature and to observe the facts which are revealed there. He developed certain methods to be used in connection with this matter of observing particular instances, and he believed that in the proper use of these was to be found the correct procedure for the progress of science.

The chief defect of Bacon's logic, as we view it today, was his failure to appreciate the importance of deductive reasoning in connection with the development of science. He did not recognize the interdependence of induction and deduction or the way in which both of these are related to the scientific imagination. But we can well understand Bacon's over-emphasis upon the importance of observing particular facts. The age which had preceded him was one which had gone to the opposite extreme. Deductive reasoning was well adapted to the authoritarian spirit of the Middle Ages, and it had been employed almost exclusively. As a consequence elaborate arguments were developed to show the implications of accepted dogmas, but little attention was given to studying the phenomena of nature. Bacon sought to correct this attitude and it was natural enough that he should over-estimate the importance of observation. The truth of the matter is that neither the imagination nor the process of deduction can be of much use unless they are supplemented by observation. To be a good scientist one must first learn to be a good observer.

Observation is a rather broad term and it is possible to distinguish many different types. We may, for example, speak of *passive* observation or that kind which is illustrated when, without any definite problem in mind, we simply observe things as they come to us in the course of our experience. This type of observation may suggest some problem or serve in some way to stimulate one's thinking along a certain line. In so far as it does this it has some scientific value, but in comparison with other types of observation it cannot be said to have very much value.

On a somewhat higher level we may place that type which we experience when we do have some definite problem in mind and when in connection with this problem we consciously search for those facts which are relevant. This is an *active* type of observation. It is an aid toward the understanding of one's problem, as well as a means of determining whether or not the hypothesis which one has in mind actually corresponds to facts as they exist in the outside world. Obviously, scientific procedure is dependent to a very large degree upon this type of observation.

A third type has to do with what is known as experimentation. Here the particular facts which are observed are those that have been obtained under carefully controlled conditions. By working out the implications of a given hypothesis one can determine what should happen whenever certain conditions are fulfilled. An experiment may then be constructed so as to fulfill these conditions, and by observing the resultant facts one can determine the adequacy of the hypothesis in question. This is again an example of the active type of observation and it plays a very important role in the solution of scientific problems.

Since the observation of particular facts is so essential a factor in the reasoning process, one needs to learn how to do it accurately. While it is impossible to lay down a set of rules which if followed will always lead to a correct view of the facts, there are certain general principles which may well serve as a guide toward an accurate survey of the relevant facts. One needs, for example, to be familiar with the way in which observation is affected by such external conditions as changes in light, temperature, atmosphere, adjacent material, time of day, and so forth. When the effect of each of these is definitely known the observer can make the proper allowance for whatever conditions are present and in this way escape the fallacies which would otherwise occur.

In addition to the physical factors of the type which has just been mentioned, there are psychological factors which influence observation, and these must also be taken into account. Such conditions, for example, as fatigue, prejudice in favor of some particular point of view, the presence of strong emotions, the purpose which one has in mind, the memory span of the individual, sensory activity, the presence of distracting conditions, and many other factors, have their influence upon the process of observing and it is only in so far as one can control these or make the proper allowance for them that he can become a good scientific observer.

A good illustration of the practical difficulties involved in making accurate observations may be obtained by an examination of the testimony given by witnesses in a criminal court trial. This is especially true in those cases in which the events described by the witnesses are such as to arouse strong emotions on the part of those who did the observing. It is only by careful training that the tendencies toward erroneous statement can be overcome.

Relation to the Scientific Imagination. As we have stated before, the three elements involved in the reasoning process are so interrelated that it is only by a kind of artificial abstraction that we can separate any one of them from the other two. We cannot say, for example, that thinking begins by observing particular instances. Active observation, as we have already noted, can take place only when we know what we are looking for, and this means that some thinking has already taken place. But if we must have an hypothesis in mind before we start observing, the question may very properly be raised, "How do we get these hypotheses?" and "What is their relation to particular facts?" It is true that these problems which we have in mind prior to our active observations may have been obtained directly from our reading or from our conversations with others. But if we pursue our inquiry still further and ask where those who wrote or talked with us obtained their ideas we are bound to be driven back somewhere to the particular observations of some individual. Presumably our own observations have led us either to question or to affirm the hypothesis that has been produced in our mind. At any rate we cannot say that hypotheses which are at all significant have come into being apart from particular observations.

Observing and theorizing about the observations go hand in hand, each one serving to supplement and complete the other. It is impossible to say just at what point our reasoning activity really begins. But we do know that in the course of its development the scientific imagination is greatly enriched by the observation of particular facts. It is only in the light of these newly observed facts that the mind can discover the inadequacies of an original hypothesis and can move forward toward the formation of a new and better one.

The dependence of the imagination upon one's experience and the range of facts which he has observed can be illustrated by calling attention to the use of analogies in connection with the formation of hypotheses. Whenever a person is confronted by a problem which arises out of a new situation, he almost invariably discovers some point of similarity between the new problem and other ones which he has experienced before. This analogy suggests some kind of a solution which may be tried out. To be sure the new hypothesis will contain some elements that are new in that they go beyond anything that has been experienced before. This is the real inductive process. It is the mind's leap from the data that has been experienced to something which is beyond it in the sense that it offers a new explanation of it. Obviously, this ability to recognize similarities and to produce new types of explanation is conditioned by the breadth of one's experience and his familiarity with the principles that have to do with related phenomena.

Relation to the Process of Deduction. As we have just noted in our previous discussion, that particular element of the reasoning process which we have called the scientific imagination cannot function to any great extent unless it is first of all supplemented by the observation of particular instances. For this reason we may say that the hypotheses which one has in mind (and these are essential for any constructive thinking), though not derived entirely from observed facts, are at least dependent upon them. It is in this sense that we may regard inductive reasoning as a process by which the mind goes from particular facts to some principle or theory about these facts.

Having reached this point in one's thinking the next step toward the solution of a problem is the working out of the implications of the general idea or principle which one has in mind. It is in this connection that deductive reasoning must be employed. For example, Galileo, before constructing his experiment concerning the law of falling bodies, found it necessary to determine just what relationships would exist in particular cases, provided that his hypothesis was true. Had he not done this before he performed his experiment, his final observation would have been of no value. But when he knew what consequences were inevitably involved in his hypothesis it was possible for him to make those particular observations which would determine whether it was a sound hypothesis.

Sir Isaac Newton could construct experiments and make those observations which verified his hypothesis concerning the law of gravitation, only after he had worked out by deductive reasoning the necessary implications of that law. Then he could observe with reference to some definite problem. But without a definite problem in mind he could not determine which facts would be relevant. A physician who wishes to make a correct diagnosis can do so only when deductive reasoning has preceded his final observations. He must know that if a certain disease is present, then certain symptoms will be present. The observance then of the presence or absence of the particular symptoms will enable him to know whether that disease is present. Thus we see that the observation of particular facts is not only an aid to the scientific imagination but also a final test of the adequacy of an hypothesis. But before it can be a test of an hypothesis it must be preceded by deductive reasoning. Deduction prepares the way for observation by determining which facts are relevant and thus making it possible to give attention to those facts which have a bearing on the problem in mind.

Hypotheses can be verified only by making deductions from them. Sometimes a single deduction is sufficient. At other times it is necessary to make many deductions and to consider the hypothesis in mind in the light of all these deductions taken together. It is possible to verify an hypothesis with a single deduction only in those instances in which one can obtain a *crucial test.* A crucial test is a single experiment or observation which establishes at once the truth or the falsity of a given hypothesis. It can be employed whenever it is possible to find some fact or condition which necessarily implies the truth of the hypothesis. It is helpful in this connection to call to mind that particular form of the hypothetical syllogism in which it is possible to obtain a valid conclusion by denying the antecedent or by affirming the consequent. For example, the proposition, "If this triangle is equiangular, it is also equilateral," is one in which the antecedent expresses an essential condition or something without which it would be impossible for the consequent to exist. Hence, we can affirm the consequent and still obtain a valid conclusion. It is on this basis that we verify an hypothesis by a crucial test. The hypothesis becomes the antecedent of a hypothetical proposition, and the particular fact or condition named becomes the consequent. For instance, I may have in mind the hypothesis that a certain kind of acid will cause a certain type of metal to become brittle. By putting a piece of this metal into a jar containing that particular kind of acid I put my hypothesis to a crucial test. Or, again, when the English astronomer Halley made the deduction from his hypothesis that the particular comet in question would appear again at a certain time, this constituted a crucial test. If the comet should appear when he said it would, his hypothesis would be verified. Otherwise it would be proven to be false.

When it is not possible to obtain a crucial test a hypothesis may be verified by what is known as a *Consilience of Results.* This means that several deductions are made from the hypothesis, and, when all of these are known to be in harmony with facts and when it is further established that the hypothesis in question is the only one which fits all of the observed facts, then the hypothesis must be regarded as true. A physician, for example, might be unable to diagnose a case on the basis of a single symptom, but if he knows many symptoms which usually characterize a disease he may be able to reach a very strong conclusion on the basis of these combined observations. It is this type of argument which is usually employed in a criminal court in order to determine the guilt or innocence of the defendant. One deduction from the hypothesis, though it was known to coincide with facts, would in most cases be insufficient to warrant a conclusion. Hence the importance of presenting a whole array of facts in order to show that the hypothesis in mind is the only one which can be made to harmonize with all of them.

The Inductive Leap. The chief objective of science, as Aristotle pointed out, is that of establishing the relationship which exists between particular facts and general principles. We say that a problem has been solved or an explanation given whenever it is possible to indicate the laws or principles which are illustrated in the particular facts that are being studied. An essential part of the process by which problems are solved is what is known as the *inductive leap.* This refers to that activity of the mind by which one goes from a few instances that have been observed to a general principle or law which governs all instances of the same kind. For example, Sir Isaac Newton in connection with his work on the law of gravitation observed a comparatively small number of instances of falling bodies but the law which he finally formulated expressed a relationship which holds between all falling bodies. The experimental scientist observes a few cases in his laboratory and then draws a conclusion concerning all the cases that are represented by the ones he has studied. Thus we see that induction is always a matter of going beyond the data that is contained in the premises. What then is the warrant or basis for this leap from a few instances to all instances? The answer to this question is to be found in the conception of the *uniformity of nature.*

In connection with the discussion of the inductive leap it should be noted that there are no valid inferences which are purely inductive. All inductive reasoning is dependent upon certain deductive considerations and without these it would be impossible to establish any sound conclusions. The conception or idea of the uniformity of nature is a kind of major premise which is implied in all so-called inductive arguments. This means that nature is so constructed that all instances which occur are typical of their kind. The particular instances of inductive reasoning may then be considered as minor premises of a deductive argument. Our only justification for a separate treatment of the inductive methods is that we wish to focus attention upon that part of the reasoning process in which new hypotheses are suggested by a consideration of particular instances, and the implications of previously formed hypotheses can be compared with actual facts. (See section entitled *The Selection and Use of Hypotheses*).

The Uniformity of Nature means that the physical universe is a cosmos rather than a chaos. Not only are particular things found together, but they belong together. In other words, nature is governed by laws and these laws are universally valid. They do not behave in one way today and in some other fashion tomorrow, but they are constant and changeless. Events do not happen by chance but are always the expression of some kind of order. Furthermore, this order which exists in the laws of nature is something that can be discovered by human minds, and in so far as it is known it can serve as the basis for prediction. Here then is the answer to the question concerning the validity of the inductive leap. The study of a few instances may be sufficient to reveal the nature of the law which governs the phenomena and this law, once it is discovered, will hold for all instances.

The significance of this conception of the uniformity of nature can be appreciated when one recognizes that all scientific procedure rests upon it. The astronomer, for example, could not successfully predict the appearance of an eclipse unless the laws that have to do with the movements of heavenly bodies remain constant and will operate in the future the same as in the past. Medical science likewise rests upon the assumption of the invariability of nature's laws, otherwise a physician would have nothing to guide him in making prescriptions, nor would he be able to predict what will happen when his instructions have been followed. The chemist, when he tells you in advance what results will be obtained when certain combinations have been made, is basing his predictions upon the same assumption. In a sense it is true that the goal of all science is prediction, but predictions are possible only on the assumption that nature is an orderly system and hence the laws of nature in so far as they are known can be relied upon to function in the future in exactly the same way as they have functioned in the past.

We have said that the conception of the uniformity of nature is an assumption. It is not something of which we can have complete empirical proof. But this does not mean that it is a blind assumption which has no basis in human experience. On the contrary it is a well warranted assumption and one that is necessary if we are to make intelligible the world of our experience. The concept is in itself an illustration of the inductive leap in that it goes beyond actual experiences to an hypothesis that has to do with all experiences. This hypothesis is, however, one that is verified by the whole structure of science, and for this reason we are justified in saying that it is true. Thus we see that the concept of the uniformity of nature, though it is an assumption, is not something that is put forward irrespective of the facts of human experience. At least a denial of its validity so far as past events are concerned would necessarily involve that which is contradictory to known facts.

Logical Methods Employed in Dealing with Particulars. These will be classified in three main groups. The first one is known as the method of *sampling*, the second one includes the methods of *experimental inquiry*, and the third one is known as the *explanatory methods*. This third group includes the method of analogy and the combined or inducto-deductive method.

The method of sampling, or enumeration, as it is sometimes called, differs from the other methods in that no attempt is made to discover a causal relation in connection with the phenomena that are being studied. When this method is employed a few instances are selected and on the basis or assumption that these instances are typical or representative of the entire class that is under consideration, one concludes that what is true of the sample is also true of the entire class.

A farmer, for example, may wish to sample a bag of seed-corn. To do this he selects a handful of kernels from the bag and plants them. If, upon examination at a later date, he discovers that only seventy-five per cent of the kernels grew, he then concludes that this is the percentage of good corn in the entire bag. If he has taken proper precautions in the selection of his sample, his conclusion will be correct, or at least approximately so. This is, of course, a very simple illustration of the sampling method.

In cases where the material to be sampled is of several different kinds the procedure is necessarily more complex. In the case of artificial samples, such as the particular questions asked in an intelligence test, it requires considerable effort and the use of many tests to determine whether the questions constitute a fair sample. Sometimes it is necessary to employ statistical methods of various types in order to sample properly the material that is under investigation. A more detailed statement of the procedure to be followed in sampling will be presented in the next chapter.

The point to be emphasized now is that the sampling method is not designed to reveal the law of the phenomena. The farmer is not dealing with the question of what makes certain kernels of corn grow and other kernels fail to grow. It is sufficient for him to know what percentage of the sample is good. And the same is true of the intelligence test. No attempt is made to determine why one's responses should be of a certain character. It is enough to know the way in which the subject responded to the sample questions and problems.

It is quite different in the case of the other methods. In each of these an attempt is made to discover the law or principle of the phenomena. It is for this reason that the validity of the conclusion which is reached is determined not so much by the number of the instances that are considered as it is by the nature of these instances and the conditions under which they are observed. In some cases a single experiment is sufficient to reveal the law of the phenomena and to multiply instances would not add anything to the strength of the conclusion.

If, for example, I wish to determine whether or not the noise produced by ringing a bell in a jar is dependent upon air, I may try ringing the bell when the jar is full of air and ringing it again after the air has been exhausted. If I find that the noise occurs only when air is present I may conclude at once that it is a necessary part of the cause.

In other instances where it is not possible to control as completely the conditions of the experiment I may take into account many instances and still be unable to draw a conclusion that is well established. If my problem is a complicated one like that of determining the relationship between heredity and the tendency to commit crime a large number of instances may be insufficient to warrant a conclusion. Thus we see that it is not the number of instances but whether or not the instances selected are sufficient to reveal the law that determines the validity of the conclusion.

QUESTIONS AND EXERCISES

1. In what sense is it true that observation of particular instances is both the beginning and the end of the reasoning process?
2. What was Francis Bacon's method? How did his logic differ from that of his predecessors? What was the chief defect of Bacon's logic?
3. Distinguish between active and passive types of observation. Give examples of each. How does experimentation differ from each of these?
4. Name several factors that influence observation and tell how these may be controlled.
5. How is observation of instances related to the scientific imagination? Discuss the function of analogy in the formation of hypotheses.
6. Show how the observation of instances is related to the process known as deduction. Illustrate with concrete examples.
7. How are hypotheses verified? When can an hypothesis be verified by a single deduction?
8. What is meant by a crucial experiment? consilience of results? Give examples of each.
9. What is the inductive leap? What is meant by the uniformity of nature? What is the significance of this concept for the development of science?

10. Explain the following statement, "The Uniformity of Nature is the ultimate major premise of all induction."
11. Select from your work in other courses an example of inductive reasoning. To what extent is deductive reasoning implied in your example?
12. What rules would you suggest that one follow in order to make accurate scientific observations?
13. Show how inaccurate observations have contributed to the establishment of erroneous beliefs.
14. From your reading of newspapers or magazines select an example of reasoning and point out the use of induction and deduction in connection with it.
15. Mention several scientific hypotheses and show how they have been verified.

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CHAPTER XII

SAMPLING AND THE USE OF STATISTICAL METHODS

The Method of Sampling. One of the methods that is frequently used for determining a general conclusion on the basis of an examination of particular instances is known as *sampling.* Sometimes the use of this method is a very simple procedure, as in the case of a farmer selecting his seed-corn or a groceryman sampling the articles of food which he wishes to purchase. But in other instances the process of sampling may be very complex involving the use of elaborate and highly developed methods of statistics. Sampling is a very useful method and one that is widely employed in many different fields of inquiry. In the practical affairs of every-day life it is frequently used to determine the character of a large quantity of homogeneous material when it is possible to examine carefully only a small amount of the same material. Sampling is also used in making scientific investigations. Through the use of this method it is possible for the scientist to survey a wide area of experience and to deal in an accurate manner with larger quantities of material than could otherwise be done.

Only through the use of carefully selected samples can one investigate such problems as the effect upon community welfare of a given type of legislation ; the relationship of tariff regulations and business prosperity; a comparison of the intelligence of racial groups ; the effect of a given economic or educational policy ; or any one of numerous other problems which have to do with the sciences of economics, sociology, educational psychology and related fields of knowledge.

Samples are of two kinds which may be designated as *natural* and *artificial.* Natural samples are selected at random from the mass of material which one wishes to investigate. The material must be homogeneous and the sample large enough to include in the correct proportion all of the qualities that are present in the entire field that is being studied. The sample will then be representative of the whole. Artificial samples are constructed for the purpose of establishing a norm or standard with which individual cases may be compared. An example of this type of sample may be found in an intelligence test or in any one of numerous vocational tests which are so widely used at the present time. When these tests are properly constructed they are extremely useful in the matter of selecting individuals for various lines of work.

A good example of a natural sample may be seen in the method used in a certain city for the sampling of coal which was being purchased in large quantities.* According to the specifications given it was required that a sample be taken of every delivery of twenty-five tons or more. The purpose of the sampling was to determine the quality and acceptability of the various shipments. Whenever a sample was taken from a boat or a railroad car those in charge of the work were careful to take it from various places and in equal amounts from the top, middle, and bottom of the pile. When the coal was unloaded by a conveyor the samples were taken at regular intervals from the moving mass. The number of samples taken was always in proportion to the size of the shipment. For a delivery that was more than twenty-five tons but less than one hundred tons a sample of at least two hundred pounds was taken. When the delivery exceeded one hundred tons the size of the sample was approximately one ton for each thousand tons. Care was taken to have the sample contain the same proportion of lump and fine coal as was present in the entire shipment. After the gross sample had been obtained the coal was reduced to a standard size and this product was sampled again. Before this sample of the previous samples was taken the coal was thoroughly mixed by shoveling it over and over and then forming a conical pile by shoveling the coal from the edges. When this was completed the conical pile was cut in half by passing a piece of sheet-iron down through the center until it struck the floor. The two halves were then separated by holding the iron plate firmly vertical and moving either half of the cone about one foot away. The iron plate was then placed at right angles to its first position and the conical pile divided into quarters. Two diagonally opposite quarters were then rejected. Following this the remaining two were thoroughly mixed, formed into a new conical pile and quartered again in the same manner as before. This procedure was continued until the final sample was no more than five or six pounds in weight. This sample was then sent to the laboratory for analysis and inspection. The materials brought to light by this analysis were judged to be present in the same proportion for the entire shipment.

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* Adapted from "Readings and Problems in Statistical Methods" by Horace Secrist, Macmillan, 1920, pp. 62-64.

This example of sampling coal illustrates clearly two important principles which must always be observed if the method of sampling is to yield a strong conclusion. The first of these principles is that the sample selected must be a "fair sample" or in other words representative of the entire class to be sampled. To make sure that the sample of coal was a fair or representative one it was necessary to do three things. First, the original samples were selected at random. They were taken from various parts of each car or pile of coal, and in the case of the coal delivered by a conveyor they were taken at regular intervals. Second, the selection of each sample was made without reference to any of the previous samples. In other words the various samples were independent of each other. Finally, the samples were put together in one pile and so thoroughly mixed that it was possible to select a sample of the samples which would represent in the correct proportion all of the materials that were present in the entire pile. The second principle which was followed had to do with the size of the original sample. When a large shipment of coal was received the number of separate samples that were taken was much larger than in the case of a small shipment.

It is true that no exact rule can be prescribed for all cases concerning the size of the sample. This must be determined in each case by such factors as the kind of material that is being sampled, the amount of variation that is present in the different parts and the degrees of accuracy that is required in the final results. However, we may say that in all instances where the method of sampling is used the question of the size of the sample used is an important one. To obtain a strong conclusion one must be sure that the sample is a fair one and that it is of the proper size to represent the whole that is being studied.

An artificial sample is used in the case of an intelligence test, a vocational test, or for that matter in the usual type of a set of examination questions. In the case of the intelligence test an individual is given a set of sample questions or exercises and his rating is determined on the basis of the responses which he makes to them. Obviously, if the test is a reliable one, it must be made up of questions and exercises which constitute a fair sample of the operations which a normal person of a particular age should be able to perform. It is for this reason that the psychologists who produce these tests exercise so much caution in the development of their norms or standards for general intelligence. For instance, they devise a separate set of questions and problems for each age level. On the basis of a wide experience and careful observation they work out a test which seems to them to constitute a fair sample for each one. But these tests have to be tried out before they become standardized. They are given to large numbers of individuals and a record is made of the score obtained in each case. If the average for the entire group is too high or too low or if the distribution of the various scores is other than it should be, the tests are changed and tried again until the requirements are met.

Vocational tests may be of the *analytic* or the *synthetic* type. In the case of the former the operation for which the applicant is being tested is divided into various parts and a separate test is given for each one. Suppose, for example, one wishes to give a test to prospective telephone operators. Since successful operators must possess such abilities as good vision, good hearing, quick reaction time, clear voice, normal memory span, etc., a test may be given for each one of these. The candidate is then rated on the basis of the score which he makes in the whole series of tests. In the synthetic test an attempt is made to construct an experiment in which the applicant will go through a series of operations of the same type as those involved in the actual work for which he is being tested. In this way it is possible to test one's ability not only with reference to the single operations involved but with reference to their combined use.

For example, Professor Münsterberg of Harvard University was asked by a street railway company of Boston to devise an experiment which they could use to determine whether a prospective motorman would be likely to run his car without accident. He constructed a device which, though comparatively simple, put the candidate through the same kind of an experience that he would have in running a street car. It was possible while the device was in operation to obtain an accurate record of the person's ability to pay attention under distracting circumstances, his reaction time, sensory acuity, ability to judge the speed of various moving objects, ability to act in case of emergency, etc. Both the analytic and the synthetic tests are illustrative of the method of sampling. In both cases the question of whether the test offered constitutes a fair sample is a complex one and can be settled only by trying it under many and various conditions. The final proof that a given test is a reliable one is that good operators when they take it make a high score while poor operators make a low one.

Statistical Methods. The method of sampling and the use of statistics are so closely related that it is not always possible to make a hard and fast distinction between them. When the problem with which one is dealing is a comparatively simple one involving the use of only small numbers and relatively homogeneous material statistical methods are unnecessary. But there are many fields of inquiry in which the problems are of a complex nature. The data which bear upon the problems must be gathered from a wide area. They must be classified and correlated before they can be interpreted in the light of logical methods. It is for the purpose of making such records, classifications, and correlations that statistical methods have been developed.

The term "statistics" was originally used in connection with matters that pertained to the state. It had to do with the records that were made of such things as births, deaths, exports, imports, governmental expenditures, etc. The taking of the census and the interpretation of the material gathered called for the development of special methods. It was in order to meet needs of this particular type that the science of statistics first came into existence. Gradually the original meaning of the term was extended so that it included not only matters of the state but other phenomena as well. The term is now used to refer to the collection and interpretation of all kinds of data in which large numbers and quantitative measurements are involved. It is important, however, to distinguish two uses of the term "statistics." The first has to do with the collection and classification of the material that is being studied. The second one has to do with the interpretation of the material or in other words with the conclusions that are drawn from it. It is true that in our actual experience we cannot entirely separate these two functions. They are to a certain extent dependent upon each other. One cannot make accurate scientific observations without having a definite problem in mind, and this means that at least a tentative conclusion is present for him as an hypothesis while he is doing the observing.

But while this is true it must also be recognized that the gathering of facts is relatively distinct from the drawing of conclusions from the same facts. The latter function belongs properly to the sphere of logic. If then we are to maintain a distinction between the fields of logic and statistics, we should confine our use of the term to the first of the two functions mentioned. With this restriction of the use of the term in mind we may speak of the use of statistical methods as devices, largely mathematical in character, which are used for the purpose of making records, classifications and correlations where the data involved include large numbers and complex material. Drawing conclusions from the materials thus assembled involves the use of logical methods. The particular logical methods most frequently employed for this purpose are sampling, analogy, concomitant variations, and the joint method of agreement and difference.

Since statistics is a separate science with a field distinct from that of logic, one should consult books that belong to that field for information concerning the particular methods that are used. But when we come to the matter of interpreting the results that have been obtained by the use of statistical methods we pass from the field of statistics into that of logic. The logician must always determine two things with reference to statistical materials. In the first place, the question of whether or not the statistics are *fair* is a logical one and it involves all of the tests and cautions to which reference was made in our discussion of the method of sampling. Secondly, the question of what conclusions are warranted by the statistical data is always a matter of logic. It is only through the use of logical methods that causal relations can be discovered or predictions made concerning the behavior of the given phenomena in the future. Failure to observe the rules that govern logical procedure is the explanation that may be given for the many erroneous interpretations that have so frequently been made concerning statistical phenomena.

The trite saying, "Figures don't lie, but liars do figure," is but one way of expressing the idea that statistics can be used in erroneous arguments. Another way of stating the same thing is to say that statistics may be used to prove anything. The truth of the matter is that statistical data if selected in a biased manner and without regard to their being fair may be used to support almost any thesis that is desired. Suppose, for example, one wishes to prove that higher education necessarily causes people to give up their belief in a Supreme Being. He may present a large number of instances where individuals who have attended institutions of higher learning have given up their former religious beliefs, and if no mention is made of other instances in which the opposite has been true, he will seem to have presented a strong argument in support of his thesis. But a logical analysis of the argument may show that the statistics used were unfair since they failed to take into account negative instances. For this reason the conclusion will be an unwarranted one.

Again, it is possible to arrive at a wrong conclusion when fair statistics are used. A good example of this type of argument is furnished by T. R. Malthus' famous theory concerning population. He presented a lot of facts concerning the rate of increase of the food supply and the corresponding rate of increase of population. He showed clearly that there is a tendency for the population to be increased much faster than the food supply and on the basis of this tendency he made the prediction that within a given period of time the world would suffer from over-population and the human race would be forced into certain types of misery in order to continue its existence. We know today that Malthus' argument was unsound for his predictions have not been fulfilled. But the fallacy in his reasoning is to be found not in the use of unfair statistics but rather in his failure to follow logical procedure in the predictions which he made. By overlooking the logical requirement of "other factors being equal" he concluded that the two rates of increase would continue in the same proportion in the future as they had in the past.

Some Terms Used in Statistical Procedure. In making a statistical investigation of any kind one of the first steps to be taken is the organization of the data. Unless the problem being studied is a very simple one, unorganized or raw statistics are of little value. For example, if one wished to study the relationship of wages paid to the employees of a certain factory and the costs of living in the town where the factory is located, it would be necessary first of all to obtain a complete record of all the wages paid to each employee over a given period of time and the costs of each of the various items included in "costs of living" over the same period of time. This data would constitute the raw materials for the study. But so long as the data remained in the same form in which it was first obtained it is quite obvious that very little could be learned from it. The investigator would need to analyze and classify the data. Since it is not likely that the wages paid would be uniform throughout the plant, it would be necessary to put the various wage-scales into different groups and find out the number of employees in each group. Since it would be impossible to deal separately with each individual and with each item included in the living costs, averages of various kinds would need to be taken. The frequency or distribution of the various wage scales would also constitute an important factor. And the same is true of the fluctuations in the living costs. In short it would be necessary to make a detailed classification and to organize thoroughly the raw materials before one could properly interpret the data which he had obtained.

It is for the purpose of reducing the unorganized data to some usable form that many of the devices employed by statisticians have been developed. These include what is known as the arithmetical mean or average, the median, mode, frequency curve, skewness, coefficient of correlation, probable error, and others. For detailed and exact information concerning each of these, one should consult a standard textbook in statistics. Only a brief and elementary statement about the meaning of some of the more common ones can be given here.

One of the simplest devices that is used not only by the experienced statistician but in the ordinary transactions of business life is the arithmetical mean or *average*. It is obtained by dividing the sum of all the numbers in a given series by the number of separate items or units in the same series. To illustrate, if one wishes to find the average grade for students in a class in logic he may do so by adding all the grades together and dividing the result by the number of students in the class. Or, one may find the average wage that is paid in a factory by taking the amount paid to all the workers together and dividing this by the number of persons included in the pay roll. This type of average has certain values. For one thing it gives a norm or standard with which any member of the series may be compared. It indicates the middle or balancing point in a series, and enables one to see at a glance how far and in what direction any one member of the series deviates from this point. But averages of this kind possess definite limitations. There are certain points which they do not reveal. They indicate nothing concerning the distribution of the numbers in the series. Thus the average wage paid in a factory may differ considerably from the amount paid to any one individual. One person drawing a very high wage would raise the average as much as several persons who received a smaller one. Again the proportion of those who receive a very small wage may be large or it may be small. Hence it is only with considerable caution that averages may be used in statistical studies.

The *median* may be defined as "the item in a series, when arranged consecutively, which divides the distribution into equal parts."* It is sometimes called an average, but, unlike the arithmetical mean, it is a measure of the distribution in a given series. It is, in other words, the size or some other characterization of the middle item in a series. This item can be obtained for a number series by adding one to the number of items in the series and dividing the result by two. For example, if we place in their consecutive order the following amounts: $2.00; $2.50; $3.00; $3.00; $3.50; $4.00; $4.50; $6.00; $7.00 we may find the median by taking the number of items in the series which is nine and adding one, and then dividing the result by two. This gives us the number five. The median then for this series will be the fifth item in the series — counting from either the first or the last item — which is $3.50. The arithmetical mean for the same amounts would be $3.93+. When the number of items in the series is an even number the mean is obtained by taking the average of the two middle items.

The *mode* may be defined as the item which occurs most frequently in a given series. Its use is not confined to numbers, for it may be applied to qualities as well. It is the kind of average that we have in mind when we speak of the size of the average workingman's house or the mental ability of the average child in the public schools. In both of these cases the term "average" refers to the one that is most common. The modal average for the wages paid to the employees of a factory would be the amount received by the largest number of persons. For example, if five persons receive $10.00 per week, 12 persons $17.00, twenty-five persons $20.00, nine persons $25.00, and six persons $32.00 the modal average would be $20.00 per week. In problems that are comparatively simple where there are few if any irregularities in the table of items the modal average is identical with the highest point in the normal distribution curve.

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* "An Introduction to Statistical Methods" by Horace Secrist, p. 255.

Skewness or asymmetry is the name used to designate the distribution of items which cannot be represented graphically by the normal frequency or distribution curve. In those cases in which the mean and the mode coincide, the items may be represented graphically by a bell-shaped curve, the highest point on the curve being used to designate that particular item which not only occurs most frequently in the series but is also in the middle of the group. A graph of this type is known as the normal frequency or distribution curve. The curve is symmetrical, the two lower points being at equal distances from the centre. But it often happens that the point of highest frequency falls either to the right or the left of this centre of distribution. When this occurs the resulting curve is said to be asymmetrical or *skewed.*

The process of establishing mathematically the relationship between two independent series of numbers is known as *correlation.* This is one of the most important operations included in the statistical methods. It is frequently used as a basis for making predictions and for establishing a causal relation between two phenomena. The essential factor that is necessary for a correlation is that the two series be so related to each other that a variation in the one will be accompanied by a corresponding variation in the other. The correlation may be direct, in which case an increase in the one series will be followed by an increase in the other, or it may be an inverse correlation which means that an increase in the one series will be accompanied by a corresponding decrease in the other. Unless the variation between the two series is a constant one there can be no correlation at all.

In certain fields of inquiry it rarely happens that a perfect correlation exists between two independent series. And yet in many of the same instances it would be incorrect to say that no correlation exists. The problem then for the statistician is that of finding an accurate mathematical expression for that degree of correlation which does exist between the two series. In other words, his problem is that of finding the *coefficient of correlation.* Several devices have been worked out for determining this relationship. Perhaps the device most frequently used is what is known as the Karl Pearson formula. This formula has been so constructed that in those instances in which a perfect correlation exists the coefficient of correlation will be $+1$; and in those instances in which there exists a perfect negative correlation the coefficient will be -1. Degrees of correlation can then be indicated by positive and negative decimal numbers ranging between these two points. When there is no correlation at all between the two sets of data compared, the coefficient is zero.

A formula for obtaining the *probable error* is another one of the devices frequently used by statisticians. Its purpose is that of determining the reliability of the results obtained by means of correlations or other statistical procedure. Since many statistical studies are based upon averages, and since these averages possess such limitations as we have mentioned, it is quite obvious that some degree of uncertainty is bound to characterize the results. What is true of the samples will not always exactly coincide with what is true of the whole which the samples represent. The amount of difference will, of course, vary with the character and size of the samples and the nature of the problem which is being investigated. The formula for obtaining the probable error is an attempt to estimate this difference for the various problems which arise. It is derived chiefly from an analysis of the difference among the samples which have been selected. For a full description of this formula and the reasons for its use one should consult some standard work in the field of statistics.

Statistical Fallacies. It is always an aid toward correct thinking to be informed concerning the fallacies which often occur in the particular type of argument which is being used. It is for this reason that an attempt will now be made to enumerate some of the more common errors which occur in connection with the use of statistical methods.

The *first* of these fallacies consists in making a prediction concerning individual items in a group when one is warranted only in a prediction concerning the group as a whole. For instance, a life insurance company can predict with a fair degree of accuracy the number of deaths that will occur within a given state or country during a stated period of time. Predictions of this sort are based upon various tables of vital statistics which have been compiled with great care over a long period of time. But while the life insurance company can predict with reference to a large group or the population taken as a whole, they cannot predict with reference to any one individual within the group.

A *second* fallacy has to do with the correlation of two sets or groups of phenomena which are entirely independent of each other. The Pearson formula for determining the coefficient of correlation may be used for any two groups of facts. Obviously then the fact that a high degree of correlation exists between two sets of facts does not necessarily warrant the conclusion that a causal relation exists between them. One might, for example, discover a high positive correlation between the production of apples in the United States and the percentage of unemployment in England; but this would not prove that one of these factors has any influence upon the other. This type of reasoning is illustrated in the theory which was put forth some years ago by an English economist who tried to explain business cycles by showing how they were related to spots on the sun. He produced a lot of statistical data which showed that business depressions occur in cycles with a fair degree of regularity.

He then showed that sun spots also occur in cycles reaching their maximum about every ten and one-third years. Since a high positive correlation existed between these two groups of phenomena he concluded that they were causally related. The theory is not accepted today. Neither economists nor astronomers recognize any necessary connection between sun spots and the various phases of a business cycle.

A *third* fallacy in the use of statistics occurs when on the basis of a high positive correlation one concludes, without any further evidence, that the two groups of phenomena in question are invariably connected in the same ratio as indicated by the coefficient of correlation. It is in the field of the social sciences that this fallacy is usually found. In dealing with questions of marriage, divorce, birth-rate, number of deaths, fatal accidents, bankruptcies, etc., one may find that there is a constant ratio between two or more of these phenomena over a long term of years. If he then concludes that this same ratio or proportion will of necessity continue in the future, his argument will illustrate this fallacy. A good example is furnished by Buckle's "History of Civilization" in which the author sought to prove by means of statistics that such phenomena as suicide, murder, etc., were governed by fixed and invariable laws and were subject to the same kind of prediction that one finds in the field of the physical sciences.

Fourth, by the use of absolute numbers in place of percentages one may seem to give support to an erroneous conclusion. For instance, a comparison may be made of the number of arrests for criminal offenses in a given state for the two respective years 1885 and 1935. If a much larger number is reported for 1935, the conclusion may then be drawn that respect for law and order has been greatly lessened during the fifty-year period. The facts may indicate, however, that the percentage of the whole population who were arrested was smaller for 1935 than for 1885, the larger number in the former case being due to the increased population. This being true, it follows that the conclusion drawn from the whole numbers was entirely unwarranted.

As a *fifth* fallacy we may mention again the use of unfair samples. One of the ways in which this is done consists of the use of a unit of classification which has a changing value. This fallacy was present in an argument used to prove that national prohibition was the cause of a higher percentage of criminals among the youth. Statistics were presented concerning the number of arrests of minors in the District of Columbia for one year during national prohibition and for one year prior to national prohibition. Since the number was much larger in the former case than in the latter, the conclusion seemed to be well established. The unit of classification was in this case the commission of a crime. But this unit had a different meaning after the prohibition law went into effect from what it had before. Drunkenness, for example, was a criminal offense during the prohibition period but not before.

QUESTIONS AND EXERCISES

1. Why is sampling included in an account of the inductive methods? Under what conditions does the method yield a strong conclusion?
2. Distinguish between natural and artificial samples. Give an example of each.
3. What is meant by a fair sample? What rules may be given for the selection of fair samples? Show how these rules were illustrated in the example given of sampling coal.
4. How are fair samples secured in the case of intelligence tests?
5. What is a vocational test? How do analytic tests differ from synthetic tests? How can one determine whether or not a given vocational test is an adequate one?
6. Discuss briefly the relationship between the method of sampling and the use of statistical methods.
7. What was the original meaning of the term "statistics"? Mention two uses of the term at the present time and show how they are related to each other.
8. Distinguish between the fields of logic and statistics. Give examples of the wrong use of statistics.
9. What is meant by the arithmetical mean? How is it obtained?
10. What is meant by each of the following: median, mode, skewness, correlation?

11. What is meant by the coefficient of correlation? the formula for probable error?
12. Describe briefly each of the five fallacies mentioned in the text in connection with the interpretation of statistical data.
13. Give examples of each of the fallacies referred to under No. 12.
14. What logical methods are best adapted for the interpretation of statistical data?
15. From your own reading or experience select five examples in which the method of sampling has been used. Criticize each one from the point of view of logical adequacy.
16. Select from your own reading two examples in which statistics have been used to support erroneous conclusions.
17. Find two illustrations for each of the following: positive correlation, negative correlation.

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CHAPTER XIII

THE METHODS OF AGREEMENT AND DIFFERENCE

Causal Relations. Whenever any two phenomena are so related that the presence of one is necessarily conditioned by the presence of the other, we say that a *causal* relation exists between them. Thus, the presence of the typhoid bacillus is the cause of typhoid fever ; the weight of the atmosphere is the cause of water rising in a pump ; the use of a particular method of study is the cause of increased efficiency ; light is the cause of the green coloring matter found in plants, etc. The term *cause* as it is used in these examples means simply an invariable antecedent of a phenomenon. To be sure most phenomena of the physical world have more than one invariable antecedent. A certain type of mosquito is said to be the cause of yellow fever. Yet it is quite obvious that other factors are just as essential and invariable for this disease as the one mentioned. But if we were to use the term cause in connection with each one of these factors it would become practically meaningless.

To avoid this difficulty we select one of the invariable antecedents and designate it as the cause of the phenomenon in question. Which factor shall be selected in a particular case is determined by the nature of the problem and the point of view of the investigator. Usually the one selected is some factor that can be controlled. In the case of yellow fever the mosquito named as the cause was subject to control. This means that it was possible to perform experiments both in the presence and in the absence of the particular mosquito in question.

The discovery of causal relations is one of the most essential factors of all scientific procedure. The goal of any science is the formulation of the laws that have to do with that particular field. But scientific laws are only expressions of causal relations. We may say, for example, that the law of gravitation is the cause of the planetary orbits or it is the cause of an apple falling to the ground. It is true that this use of the term is a broader one than was described in the preceding paragraph, for the law of gravitation is not some one factor that may be controlled for the sake of experimentation. But the formulation of this law is based on experiments in which conditions were controlled and particular causes noted.

So if we raise the question, "What is the law of gravitation?" our answer will be that it is a general statement concerning invariable antecedents. It is an expression of the constant relations which hold among falling bodies. Similar accounts may be given for other scientific laws. The question of an ultimate cause, or, in other words, a reason why the laws of nature operate as they do, does not belong to the realm of science. It is a problem of metaphysics. Hence this meaning of the causal relation should be excluded from logic as it is from the various fields of science.

It is important to distinguish in this connection between causal relations and the universal principle of causation. The former have to do with the causal nexus which exists in particular instances while the latter is the general principle upon which all causal relations and all of the laws of science depend. The law of causation may be stated as follows: *For every phenomenon in the universe there exists an adequate cause.* This means that events do not happen by chance. Some constant or universal law of nature is illustrated in every event that takes place. This law means essentially the same thing as the principle of the uniformity of nature which was discussed in Chapter XI. The essential significance of this concept is that nature's laws are uniform. They operate in the future the same as in the past and for this reason predictions can be based upon them. The term "law of causation" is used to give emphasis to the idea that nature is a system with the parts so arranged that for every event which occurs there exists another event or circumstance without which it could not occur and in the presence of which it must occur. Universal causation is a postulate of science. It is presupposed in every account of the laws of nature. But it is not this principle that we have in mind when we speak of the scientific discovery of causal relations. It is rather a matter of the nexus or relation which holds true of the particular phenomenon that is being studied.

How are causal relations discovered? Different answers to this question have been given by various logicians. Aristotle held that the general principles or laws of science are recognized intuitively after particular instances have been studied. Medieval logicians who recognized the validity of only deductive reasoning believed that the laws of nature could be known only as they were deduced from an established authority. Francis Bacon went to the opposite extreme when he maintained that the observation of particular instances was not only a sufficient means for discovering the laws of nature but that a true knowledge or understanding of nature could be gained in no other way. For him deductive reasoning was but a useless relic of medievalism which the man of science ought to discard. A new emphasis upon the importance of deduction was given later by such eminent men as Thomas Hobbes, René Descartes, Sir Isaac Newton, and the astronomer, William Herschel. But when John Stuart Mill published his famous work called *A System of Logic* in 1843 it was the spirit and method of Francis Bacon that characterized his thought. Bacon's three tables, of agreements, of differences, and of variations, were further developed into what became known as Mill's five experimental methods for discovering causal relations. These were the methods of agreement, difference, the joint method of agreement and difference, concomitant variations, and residues.

Mill believed that these five inductive methods were both adequate and necessary for the discovery of causal relations. That these methods are useful in formulating the laws of science no one can deny. But whether their chief function is discovery or verification is a matter concerning which there is difference of opinion. We are of the opinion that they are primarily methods of verification. The reason for this position is that the observation of instances can be of little if any value unless they are guided by some definite principle and made with reference to some particular problem. The Mill methods all presuppose the selection of certain instances and these cannot be made without prior reflection. To be sure the use of these methods serves to correct and to supplement the hypothesis which one has in mind. The reasoning process is, as we have said before, a unit, and we cannot maintain that one part of it is more important than another. But while we recognize that there may be some elements of discovery in the Mill methods it seems best on the whole to treat them as instruments for verifying hypotheses.

The Selection and Use of Hypotheses. The value of the Mill methods as instruments for the progress and development of science can be seen most clearly if we consider them in relation to the work of selecting good hypotheses. Hypotheses or tentative explanations are essential for the solution of all kinds of problems. They are used in every field of scientific research, and they are also necessary for the solution of problems which arise out of practical every day experience. Even the observation of facts, in order to be valuable, must be guided by some hypothesis. One does not solve problems by merely observing facts in general. Observations must be made with reference to some tentative explanation. Otherwise one does not know what to look for. Neither can he distinguish between relevant and irrelevant facts. Progress in any field of knowledge could well be described in terms of an advance from inadequate to more satisfactory hypotheses.

For the purpose of using a simple illustration, let us suppose that someone is driving a motor car when suddenly the engine stops and refuses to function. The problem of course is that of finding the cause of the motor trouble. Obviously, one could not determine the cause of the difficulty by merely looking at the car. To be sure, he could, by so doing, observe many facts. But he would not know *which* facts were causally related to the stopping of his motor.

Before he could arrive at a correct solution of his problem he would have to have some hypothesis in mind and make observations with reference to it. He might, for example, proceed on the assumption that the battery was run down. With this explanation in mind, however, it would be possible to make observations that would determine at once whether this hypothesis was the correct one. He could turn on the lights and if they functioned properly he could be sure that the battery was not at fault. With this hypothesis out of the way, he would next proceed to the consideration of another possibility.

Let us say that he now works on the assumption that the gas line is clogged. By an examination of the carburetor he can determine whether this explanation is the correct one. If the carburetor receives plenty of gasolene he may be sure that he has not yet located the source of the trouble. It will then be necessary to try another hypothesis, and so on, until he finds one that is in harmony with all the relevant facts which he may observe.

Research problems in any field of scientific inquiry are necessarily carried on in a similar manner. When Pasteur began his investigations concerning the origin and transmission of hydrophobia, he took into account a number of hypotheses, and, through a series of experiments and observations, proceeded to test the validity of each one. At first, he worked on the assumption that saliva taken from the mouth of a dog that has died from hydrophobia will always be sufficient to transmit the disease. Through a number of experiments which he performed under carefully controlled conditions he made sure that this hypothesis was not a valid one. He then gave his attention to other possibilities which could also be verified or rejected through experimentation. Finally, he began to work on the hypothesis that the medulla of an animal infected with hydrophobia would constitute a sure means of transmitting the disease. This explanation proved to be in harmony with all the facts which his experiments had brought to light and for that reason he accepted it as true.

The historian in his efforts to reconstruct the events of the past can carry forward his investigations only by giving careful attention to hypotheses. Suppose, for example, one wishes to determine the causes of the world war which began in the summer of 1914. It would be impossible to take into account all the facts that were present during the months that preceded the outbreak. And yet one must consider some of the facts. But, we may ask, which facts are deserving of one's attention? This question can be answered only in the light of the hypothesis which one has in mind. The explanation which one is seeking to verify is the only thing that can determine the relevancy of the facts. It may be that the desire for huge profits on the part of those who were engaged in the manufacture of munitions was a major cause of the war. Once this hypothesis is accepted, a wide range of facts immediately become relevant. The profits of the various companies, and the amounts of dividends which were declared to their respective stockholders, along with many other facts would tend either to verify the hypothesis or indicate that it should be rejected. Other hypotheses, such as the growth of nationalism, desire for economic supremacy, fear of conquest by foreign powers, etc., could then be examined in the same way.

The use of hypotheses is equally essential for the solution of problems that belong to the fields of law, ethics, art, or religion. It is only by a comparison of the respective merits of rival hypotheses that progress can be made in any field of knowledge. Now it is with reference to the selection of good hypotheses that the methods proposed by John Stuart Mill are useful. These methods do provide a means for determining whether the hypothesis which one has in mind corresponds with the facts which actually exist in the world of our experience. Herein lies their significance as instruments for the progress and development of knowledge.

The Method of Agreement. The first of these methods is based upon a study of affirmative instances or cases in which the phenomenon to be investigated is present. Mill regarded this method as an instrument for the discovery of causal relations. The canon or rule for its use, as formulated by him, is as follows: *If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon.*"*

Suppose that an outbreak of typhoid fever has occurred in a certain community and an official from the health department has been called upon to find the source of contagion. The health officer would of course know something about the nature of typhoid fever and the many ways in which the disease may be transmitted. This knowledge would enable him to select factors that are relevant and thus to form good hypotheses concerning the cause of the epidemic. Knowing that the disease germs can be carried by an impure water supply, infected milk, or any one of various kinds of contaminated food, he would examine all of the cases of typhoid fever in the community for the purpose of discovering a single factor common to all of them. If he should find that water from the public supply was the only common relevant factor, all of the others being sometimes present and sometimes absent, he would conclude by the method of agreement that the public water supply was the cause of the outbreak of the typhoid fever.

Or take the case of a student who is working in a psychological laboratory on the subject of negative after-images. He has observed that whenever one looks steadily at a small colored square placed on a white or gray background the edges become somewhat blurred and the area that is adjacent to the square is tinged with a different color. To determine the cause of this phenomenon he performs a series of experiments, varying the conditions in each instance. At one time he uses a red square on a white background and observes a blue-green after-image; at another time he uses a blue square and observes a yellow after-image; again he uses other colors and obtains different results. He performs the experiment again with colored backgrounds and so on until he has a large number of instances. In searching for a common factor, present in all of the instances of negative after-images, he finds that the only one which is at all relevant to his problem is the presence in each case of a complementary color. He thus concludes by the method of agreement that this is the cause of the phenomenon.

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* J. S. Mill, *A System of Logic*, p. 451.

The use of the method of agreement does not, however, guarantee a correct or sound conclusion. It is possible in many if not in the majority of cases to select a common factor which has no causal relation to the phenomenon under consideration. Thus I may argue from a militaristic point of view that war is the cause of a nation's greatness since all the great nations of the present day have engaged in warfare. Or I may try to prove that criminal traits are inherited by showing that bad ancestry is a common factor in the case of a large number of persons who have been convicted of crime. Many of our popular superstitions are based upon the same type of argument. The number 13 is supposed to be the cause of bad luck, since it has been connected in some way with each one of a large number of unfortunate experiences. In all three of these examples the method of agreement is used and yet the conclusion is obviously unsound in each case. Naturally, then, the question arises, "How can one tell when this method is used whether or not the conclusion is sound?"

In the case of inductive arguments it should be remembered that it is never possible to achieve absolute certainty. For this reason we always characterize the conclusion as being strong or weak rather than true or false. Hence our question becomes, "Under what conditions will the method of agreement yield a strong conclusion?" In general it may be said that a strong conclusion is obtained whenever the common factor selected as the cause can be shown to be the only relevant common factor. In other words, the method yields a strong conclusion only in those cases where all of the irrelevant factors have been excluded. Thus in the case of the typhoid fever investigation the conclusion that the source of contagion was to be found in the public water supply would be well established provided that all other factors such as impure milk, infected food, etc., had been excluded by showing that no one of them was common to all of the instances of typhoid fever.

The method of agreement, though valuable as a means of verifying hypotheses, has certain limitations or defects with which anyone using the method should be familiar. In the first place it is not sufficient by itself for discovering any new causal relation. In those instances in which one or more probable causes are already known it can be used without any difficulty. But if we are dealing with some problem where nothing concerning the answer is known in advance; if we are trying to find the cause of repeated drouths in the middle-west or the cause of baldness among men, we are unable to distinguish between relevant and irrelevant factors and thus it becomes impossible to proceed on the basis of this method. This is one of the reasons why it seems best to regard the Mill methods as instruments for verification rather than discovery. But a second defect comes to light when the method of agreement is considered as a means for establishing the truth of an hypothesis. As stated in the preceding paragraph this method yields a strong conclusion only after irrelevant factors have been excluded. But there are instances where this cannot be done. Take for example the problem concerning the cause of criminal traits. There are two common factors present in all criminals, viz., heredity and environment. But it is impossible to exclude one or the other of them. Hence there is no way of determining, so far as this method is concerned, whether one of them is an irrelevant factor. Again the fact that several instances of a given phenomenon reveal the presence of a certain common factor is no positive proof that this factor is invariably present.

The method of agreement is thus seen to be inadequate as a means of discovering causal relations, and it is not an infallible instrument for establishing the proof or verification of an hypothesis. Nevertheless this method does have an important place in scientific procedure. It is an aid toward the elimination of false hypotheses. This is accomplished chiefly through the negative aspect of its use. We can always be sure that any factor or circumstance is not the cause in question if it is not common to all the instances of the phenomenon.

The Method of Difference. The second of Mill's experimental methods is based upon the comparison of an instance in which a given phenomenon occurs with another instance in which it does not occur. It deals in other words with the question of the presence and absence of particular circumstances. By its use Mill hoped to overcome some of the difficulties involved in the method of agreement. The canon for the method of difference is stated as follows: "*If an instance in which the phenomenon under investigation occurs and an instance in which it does not occur, have every circumstance in common save one, that one occurring in the former; the circumstance in which alone the two instances differ, is the effect, or the cause or an indispensable part of the cause of the phenomenon.*"*

This method is particularly adapted to certain fields of experimental science. Whenever it is possible to control the conditions of an experiment so that only one factor is varied at a time, this method can be used to good advantage. If I wish to determine the effect of sunlight upon the growth of a certain kind of plant, I may do so by first observing the growth that takes place during a given interval when the plant is freely exposed to the sun's rays and then comparing it with the growth made under similar conditions but with sunlight excluded. The difference in the results obtained in the two instances will be the effect due to the presence of sunlight. Or, we may take the familiar example of ringing a bell and the problem of whether or not air is essential for the noise which follows. First we may ring the bell in a jar that is full of air and observe the noise which occurs. We then exhaust the air from the jar and find on again ringing the bell that there is no noise. Here then is an instance in which noise is present and another instance in which it is absent. The circumstances attending the two instances are the same with the single exception that air is present in the one case but absent in the other one. We thus conclude by the method of difference that air was an essential part of the cause of the noise.

A physicist, chemist, biologist, or any scientist who works in a laboratory under carefully controlled conditions will make frequent use of the method of difference. Whenever the effect of some particular factor or circumstance is in question, tests can be made with this factor present and again with it absent. The difference in result will be the effect of that factor.

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* J. S. Mill, *A System of Logic*, Vol. I, p. 452.

There is one rule which must always be observed if the method of difference is to yield a strong conclusion. *Vary only one factor at a time.* Whenever more than one factor has been varied in a single experiment, one cannot be sure whether the difference in result is due to one particular factor or to another, or to a combination of factors. In laboratory experiments where the circumstances attending a given phenomenon can be controlled at will, this rule can usually be followed and as a result strong conclusions are obtained. But there are some fields of investigation in which it is rarely possible to vary only one factor. This is generally true of problems in the social sciences and for this reason the method of difference will seldom yield a strong conclusion in these fields.

The use of this method when more than one factor has been varied is one of the most common types of fallacious argument. The following will serve as an example. I find as I look at the stock-market quotations in today's newspaper, that the price of wheat has gone up six cents per bushel. I also notice in the same paper that there are new indications of an approaching European war. Since the rise in the price of wheat did not occur until news had been received of the new indications of war I may conclude by the method of difference that a causal relation exists between these two circumstances. But this conclusion is not a well established one since other factors in addition to the war news have also been varied and the advance in the price of wheat may be due to one or more of them. In the same way it may be argued that the passage of a high tariff bill is the cause of business prosperity by showing that prosperity is present when the tariff law is in effect and absent when it is not in effect. But this conclusion does not follow unless it can be shown that no other factor relevant to the problem has been varied.

The method of difference is a valuable instrument for verifying hypotheses and thus establishing causal relations. But like the method of agreement it has certain limitations which should be kept in mind. The method is not, as Mill believed, adequate for the discovery of new causal relations. To use the method correctly one must vary only one factor at a time. But does this mean only one factor that is relevant to the problem? If so, we have the problem of determining just what factors are relevant and this means knowing at least the probable answer in advance. If it does not mean relevant factors but any factor at all, it can be said that no situation ever arises where it is possible to vary no more than one factor. We must then consider this method as a principle of proof rather than discovery. But even here the use of the method does not guarantee correct conclusions. We still have the same problem about relevant factors and the doubt may arise as to whether or not any of the other factors that have been varied are relevant to the problem under consideration. Hence we may say of this method as we did of the method of agreement that its chief value is to be found in connection with its negative use. It does enable us to know that certain factors are not the cause.

We might formulate a principle for the negative use of the method of difference as follows: "That is not the cause of a phenomenon in whose absence the phenomenon occurs." When the method is used in this way it becomes a valuable supplement to the method of agreement. The following example furnishes illustration of this use of the method.

AN OUTBREAK OF TYPHOID FEVER IN CEDAR FALLS, IOWA

[Based on the report of Arthur L. Grover, *Journal of Infectious Diseases*, Vol. 10, No. 3, pp. 388-398]

Cedar Falls is a city of about 5,000 inhabitants situated on Cedar River in Blackhawk County, Iowa. It is the home of the Iowa State Teachers College where about 1,100 students are annually enrolled. During the early part of November, 1911, there occurred throughout the city an epidemic of typhoid fever. A representative of the State Board of Health was assigned to make an epidemiological investigation and to report on the conditions in

Cedar Falls. This investigation was started on the 8th of November.

Samples of water were taken at various points from the public supply and sent to the laboratory for bacteriological examination. The study of individual cases was then commenced. Visits were made to the homes of those reported sick with typhoid fever and the information obtained was carefully recorded and tabulated. After 80 cases had been examined it seemed that sufficient data had been obtained for drawing final conclusions. The chief facts and conclusions will be enumerated so that the results and the manner in which they were obtained may be seen.

At the time of the investigation there had been reported by the physicians 95 cases. Later reports brought the number up to approximately 200. The death-rate was approximately 10 per cent which is about the usual rate for a water-borne typhoid-fever epidemic. The diagnosis was confirmed in a great many cases by the Widal test. This is a blood test which determines with high accuracy whether the patient has typhoid fever.

With the exception of the students, nearly all of the persons infected had lived in their regular residence for more than a year. Thus previous residence was excluded as having any bearing on the outbreak. And since the percentage of those who were sick was no higher for any one occupation than for another, that factor was also excluded.

There was a greater proportion of the cases among the students, but these of course were all of the typical "typhoid age." There was no large proportion of very young children infected. The places of business of those infected were found to be distributed throughout the city. The sanitary conditions of the premises were excellent.

The season, the distribution, and the general character of the outbreak eliminated flies and other insects as the cause of the outbreak. Every house had been screened during the previous summer. There had been no unusual amount of wind and apparently no dust at the time of the infection. Also, there was no history to be obtained that would point to either carriers or contact as a cause of the epidemic. From the explosive type of the outbreak we know that the infecting agent must have been spread by some beverage or food. With the exception of the students nearly all had obtained their food in their own homes.

The milk supply was most carefully examined both with reference to the source of supply for those who were sick and by a careful inspection of the dairies involved. Forty of the patients had taken milk as a beverage, twenty had used it with cereals, thirteen had not used it in any form, and information could not be obtained in one case. Thus sixteen per cent of those sick with typhoid fever had used no milk at all. The milk dealer with the largest number of customers had the most cases among his patrons,—in other words no one milk dealer had a number of cases disproportionate to the size of his business.

Previous epidemics that have been traced to milk as the source of contagion have usually had the following characteristics : Several cases have been present in a single family, prodromes (premonitory symptoms of the disease) have been absent due to virulence of the infection organisms — milk being such a good culture medium for the typhoid bacillus — and the larger percentage of those sick were of the "milk-drinking" age, or in other words young children. Those of any age drinking milk as a beverage will of course show the greater proportion of infections. None of these characteristics were present in the Cedar Falls epidemic.

Many dairies were visited and samples of their well water were taken and examined. These examinations showed no evidence of carriers or contaminated wells where the milk was produced. It was learned that one of the men engaged in handling milk in connection with one of the dairies had been sick with typhoid fever and later died from the disease. His death occurred about the first of November. However when all the data concerning milk had been obtained, it was decided that this factor could not have been the infecting agent.

Forty-one of those sick with typhoid fever had eaten ice cream. Of these sixteen had obtained it at one place, eight from another place, and the other seventeen at both places or at home. Both the ice cream manufacturers had their own private source of cream and denied trading from one to the other. All the dairies supplying these two places were inspected but no possible source of infection was found. Milk and ice cream were finally ruled out chiefly because of the fact that the disease as manifested in this epidemic did not resemble a "milk-type" of infection and for the other reasons given above.

All the grocery stores in the city, with one exception, obtained their butter from a local creamery in the surrounding country. The owners of this creamery appeared to be keeping a very careful watch over their producers and had reports of sickness from only two places (one scarlet-fever and one small-pox). The milk from these two places was immediately discontinued. It was impossible to look into all these sources of cream. However it was learned that two of those sick with typhoid fever had purchased their butter from a store not supplied by this creamery, and many of the college boarding-houses had obtained their supply from farmers who brought it in from the surrounding country. On these grounds further consideration of butter was given up.

Apples and grapes had been eaten by about all that were sick with typhoid fever, but the sources of supply were so various and scattered that the produce from any one place would have been eaten by less than fifty per cent. of those infected. Many of the people raised their own celery and the remainder obtained that which had been raised by one gardener who used deep well water with which to irrigate and wash the celery. The water from the well when examined proved to be good. Therefore, on account of the small percentage of persons who had used this celery and from other data obtained in regard to other phases of the subject, celery was ruled out as the inciting factor. Other vegetables were eaten raw but by a very small percentage — less than twenty-five — and the vegetables and their sources were, as in the case of apples, varied and scattered. Raw shell-fish had been eaten by only one or two. Only a few persons had taken a trip out of town at the time of the infection. There was no history of previous typhoid or intestinal trouble to be obtained, whether in the households where sickness was found or in the households of their servants. Thus carriers as the source of infection was ruled out.

In regard to the water that had been used it should be mentioned that the city of Cedar Falls had long prided itself on the matter of the purity of their water supply. Chemical analysis made at the beginning of the investigation had failed to detect any pollution with sewage material. The chlorine and nitrate content were always high and showed some variation but this had been explained as coming from natural sources. The source of water supply for the city is a collection of springs at the foot of a hill southeast of the city. The location of these springs is lower than the city itself and also lower than most of the surrounding country. The springs are enclosed with brick and covered by a roof. A wooden conduit conducts the water by gravity from the springs about one thousand feet northeast to a brick and cement collection cistern from which it is pumped directly into the city mains. The pumping station is situated beside the cistern. The excess pumpage overflows from the mains into a water tower some distance from the water plant on a high ridge of land in the central portion of the city.

The formation from which these springs issue is what is known as the Cedar Valley limestone and is a broken formation full of faults and water runs. Most of the drilled wells in the surrounding country go down to this same stratum. It is generally admitted that during high water or after severe rains the water from these springs is apt to be roily; also that the water in the drilled wells becomes roily. These facts in addition to the knowledge that the geological formation tends to intercommunication between the various sources of ground water, show that at times there certainly has been contamination with surface water.

On October 19 and 20, the flour mills in Cedar Falls had to shut down on account of high water, the water being four and one-half feet deep and taking several days to return to normal. It requires about a two-foot rise to cover the spring overflow. The high water followed the flooding of the head-waters of the river and did not take place until four or five days after the heavy local rains in October. Now the previous season was one of almost no rainfall and this October rain had therefore an unusual amount of surface contamination to wash into the river. The river thus became a much more concentrated source of contamination than for a long time previous. The time of the high water and that of the infection were the same. On October 20 and 21 the college filled its swimming pool and made a somewhat extra draw in that direction. It was noticeable that a large number of cases appeared in the general direction of the college and along the principal main. The standpipe takes the excess pumpage by a pipe running to it from the principal main. It is possible that infected water may have been pumped into the tank at night when little was being used and only distributed the following morning. Water from this public supply is seen to be the only factor in common, and for this reason the conclusion has been reached that it was the source of contagion.

Notes on the Typhoid Epidemic at Cedar Falls

This investigation furnishes a concrete illustration of each of the three elements included in the reasoning process. It shows, further, the way in which these three elements are related in the actual work of finding a solution for a particular problem. The scientific imagination was involved first of all in the definition of the specific problem and again in each one of the hypotheses put forward for its solution. Deductive reasoning was employed in working out the implications of each hypothesis. Finally, the verification or rejection of each hypothesis was accomplished by the use of one or more of the experimental methods.

In connection with the process of verification three points are clearly illustrated. The first one is the negative use of the method of difference; the second one is the affirmative use of the method of agreement; and the third is the final verification of the hypothesis by a consilience of results. These three points will now be considered in the order named.

1. The negative use of the method of difference is employed with reference to each of the following items:

(a) Unsanitary condition of premises. Typhoid fever was present where the sanitary conditions were reported as excellent. This factor could not then be the cause of the epidemic, for that is not the cause of a phenomenon in whose absence the phenomenon appears.

(b) Geographical location was excluded as a cause of the epidemic since the disease was present in all parts of the city. Hence the cause must be found in connection with some factor affecting all parts of the city rather than some isolated area.

(c) No one occupation could be causally connected with the epidemic, for nineteen different occupations were represented among the eighty patients examined. Hence typhoid fever was present in the absence of any one of the various occupations.

(d) Flies and other insects could not be the cause of infection in this epidemic since they were absent in most of the instances where typhoid fever was present. Practically all of the houses had been effectively screened during the previous season.

(e) Wind and dust were likewise excluded as carriers of the disease germs. This inference was strengthened by the fact that in no case could any information be obtained that would point to carriers or direct contact as the source of contagion.

(f) Milk was excluded as a causal factor by the negative use of the method of difference. Sixteen per cent of all the patients examined had used no milk at all. However this inference when taken by itself would not have been sufficient for ruling out milk. Milk is an exceptionally good medium for the culture of typhoid germs and eighty-four per cent of those sick had used milk in some way. But the usual characteristics of a milk-borne typhoid fever epidemic were not present at Cedar Falls and this fact in addition to the argument based on the negative use of the method of difference was the reason for concluding that milk was not the medium through which the infection was carried.

(g) Ice cream was ruled out as a causal factor for the same reason as given in the case of milk. Many of the patients had not eaten ice cream, and besides the epidemic did not bear the ordinary marks of a milk-borne type of infection.

(h) Butter was also eliminated as a cause. The main source of supply had been carefully guarded against infection, and a considerable portion of those infected had obtained butter from another source. Hence there was no one source of butter that was present in all the instances of those infected.

(i) Vegetables, shell-fish and other articles of food were also eliminated as causal factors since they were absent in some of the cases where typhoid fever was present.

2. The affirmative use of the method of agreement is illustrated in the argument concerning the public water supply. All of those who were sick with typhoid fever had used water drawn from the public supply. Here then was a common factor for all of the instances under investigation. Furthermore, previous experience had proven clearly that water is a relevant factor since it is frequently a carrier of the typhoid germ. The method of agreement was used twice as follows:

(a) At the beginning of the investigation water was selected as a possible cause of the epidemic. It was evident that water was a common factor and one that is frequently known to be the source of contagion. It was with reference to this hypothesis that tests were made of water taken from the public supply. But the method of agreement did not yield a strong conclusion in this case, for it had not been proven that water was the only common factor relevant to the problem. There was still the possibility that the cause of the epidemic was any one of several factors, such as milk, ice cream, dust, carriers, etc.

(b) The second use of the method of agreement appears after a whole series of possible causes had been ruled out by the negative use of the method of difference. After it had been proved that the cause was not bad sanitary conditions, geographical location, or any one of the various kinds of food and drink mentioned, it was evident that water from the public supply was not only a common factor, but the only common factor that could have carried the infection in this epidemic. Hence a strong conclusion was reached from this second use of the method of agreement.

3. The final verification or rejection of an hypothesis by a consilience of results is illustrated as follows:

(a) The hypothesis concerning milk was somewhat in doubt due to the fact that there were some indications that milk was the infecting agent, but other evidence pointed in the opposite direction. The decision was made by first noting the implications of the hypothesis concerning milk and comparing these with conditions at Cedar Falls. Since milk-borne typhoid fever epidemics are usually characterized by the presence of several cases in a single family, by the absence of prodromes, and by a larger proportion of cases among small children it would follow, on the basis of this hypothesis, that these conditions would be present at Cedar Falls. But the facts showed clearly that none of these conditions existed in the present epidemic, and for this reason the hypothesis concerning milk was definitely rejected.

(b) The hypothesis concerning the public water supply was verified by the same type of reasoning. The implications of this hypothesis, or, in other words, deductions made from it, were to the effect that some source of contamination must have existed in connection with the public water supply and further that it must have been present at a particular time prior to the outbreak of the epidemic. Investigation of the springs, cistern, and water conduits revealed that there was abundant opportunity for polluted surface water to enter the public supply. The time of the heavy October rains corresponded closely with the time when the infection must have been spread. When all of the factors had been considered it was evident not only that the hypothesis concerning city water was in harmony with all the known facts, but that it was the only hypothesis by which these facts could be explained. Therefore the hypothesis must be true.

QUESTIONS AND EXERCISES

1. What is meant by a causal relation? Are scientific laws expressions of causal relationships? Give reasons for your answer.
2. Why is the question of an ultimate cause said to be outside the sphere of science?
3. What is the law of universal causation? What is the logical basis for this law?
4. Distinguish between the law of universal causation and the causal relations with which science has to deal.

5. How are causal relations discovered?
6. Why did John Stuart Mill regard his five experimental methods as principles of discovery? Why, according to the text, are they regarded as principles of verification?
7. State the canon for the method of agreement. Give a concrete illustration of its use.
8. When does the method of agreement yield a strong conclusion? Give an example of its use where the conclusion is weak.
9. What is the chief value of the method of agreement? Give reasons for your statement.
10. State the canon for the method of difference. Give a concrete illustration of its use.
11. Explain the affirmative and the negative use of the method of difference. Illustrate the negative use.
12. When does the method of difference yield a strong conclusion? Give an example of its use where the conclusion is weak.
13. Give an account of the way in which the negative use of the method of difference was employed in the investigation at Cedar Falls.
14. Why did the method of agreement as it was used at the beginning of the investigation fail to prove that water was the source of contagion?
15. Why did the same method yield a strong conclusion concerning water at a later stage of the investigation?
16. Discuss the reasoning involved in the rejection of the hypothesis concerning milk.
17. Show how a consilience of results was used to verify the hypothesis concerning water.
18. Select from your own reading or experience two examples of the method of agreement. Show how these examples were used to verify hypotheses.
19. From your reading of newspapers and magazines select two examples of the negative use of the method of difference.
20. Select from similar sources two examples of the affirmative use of the method of difference. How do you determine the validity of the conclusion in each case?

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CHAPTER XIV

THE JOINT METHOD OF AGREEMENT AND DIFFERENCE

Nature and Use of the Joint Method. The joint method of agreement and difference was devised by John Stuart Mill for the special purpose of dealing with problems where a strong conclusion cannot be reached by using either the method of agreement or the method of difference. We have seen that the method of agreement cannot yield a strong conclusion except in those instances where all of the irrelevant factors have been excluded. In other words, it is essential that a single common factor relevant to the problem be selected as the cause of the phenomenon. But there are some instances where it is impossible to meet this condition because there is no way of telling, so far as the method of agreement is concerned, which one of several common factors is really relevant to the problem.

Suppose our problem is that of finding the cause of a crime wave which has just appeared in each one of a whole group of cities. In searching for the factor that is common to all the instances we discover a dozen circumstances each one of which is present in every city where there is a crime wave. We cannot conclude that all of these circumstances are causally related to crime. Yet there is no way of knowing which ones are so related. It is necessary then either to abandon the problem or to find some other method for dealing with it.

A similar difficulty may be encountered with the use of the method of difference. This method, as has been stated before, can yield a strong conclusion only in those instances where a single factor has been varied at a time. But there are some fields of investigation where it is impossible to vary only one factor. This is particularly true in the field of the social sciences. For example, one could never find two towns or two communities that do not differ in more than one respect. If our problem is that of finding the cause of a crime wave in a certain city, we might compare the conditions that are present in the city where the crime wave is found with the conditions that are present in another city that has no crime wave, and conclude that some circumstance, present in the first instance but absent in the second one, is the cause of the crime wave. But the conclusion would not be well established. A critic of the argument could always point to some other circumstance that was present in the first city and absent in the second one and urge with equal force that it was the cause of the phenomenon. Obviously, the method of difference would not be adequate for dealing with this problem.

In order to overcome difficulties of this type involved in the use of the method of agreement and the method of difference Mill devised the joint method. This third method involves a comparative study of two sets of instances. The first set is made up of instances in which the phenomenon under investigation is present. The second set is drawn from the same field of inquiry, but it is made up of instances in which the phenomenon is absent. These two sets of instances are compared and the circumstance that is invariably present in the first set of instances but invariably absent in the second set is said to be causally related to the phenomenon.

The method is thus seen to be a combination of the principle used in the method of agreement and the one used in the method of difference. The principle of agreement is involved in the selection of a common factor in each set of instances. The principle of the method of difference is involved both in the fact that the phenomenon under investigation is present in one set of instances and absent in the other set, and again in the fact that the common factor in the second set of instances is the absence of the common factor present in the first set.

Mill's statement of the canon for the joint method is as follows: *If two or more instances in which the phenomenon* *occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance; the circumstance in which alone the two sets of instances differ, is the effect, or the cause, or an indispensable part of the cause, of the phenomenon."* *

If we return now to the problem concerning the cause of a crime wave in a group of cities we find that the joint method may be used in the following manner. An analysis is made of the circumstances present in each of the cities where a crime wave exists. The circumstances enumerated would, of course, include only those factors which might be causally related to crime. We will suppose that among these circumstances thus enumerated there is one which is invariably present, but that each of the other factors is sometimes present and sometimes absent. These data will then constitute the first or affirmative set of instances.

For the second or negative set of instances it is necessary to select a group of cities in which no crime wave exists. These instances must be selected from the same field of inquiry as the ones in the first set. This means that the cities selected must be ones that are similar in many respects to those included in the first set of instances. For example, they should be cities of approximately the same size, the same nationalities should be represented, the economic conditions should be similar, etc. If in this second or negative set of instances the only common factor is the absence of the circumstance that was invariably present in the first set —each of the other factors being present in some cities but absent in others—the conclusion would then follow that the single circumstance which was invariably present in the first set and invariably absent in the second set is the cause of the crime wave.

The cause of divorce is another problem which might be investigated by using the joint method. Let us suppose that our data for this problem are to be derived from a study of fifty couples; and further, that seventy-five per cent. of these couples have been divorced but the remaining ones are living happily together. The circumstances which might be conducive to divorce will, of course, be varied in individual cases. But if a study of all the relevant factors should reveal that there is one circumstance that is invariably present in the case of all the divorced couples but invariably absent in the case of all those not divorced,—other factors so far as the two sets of instances are concerned being approximately equal,—we would be warranted in drawing the conclusion that this one circumstance is the cause of the divorces in question.

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* J. S. Mill, *A System of Logic*, Vol. I, p. 458.

This description of the joint method together with the examples given of its use is sufficient to illustrate some of the weaknesses as well as the merits which are involved in it. In all probability it would not be possible to find data that correspond exactly to either of the examples that have just been described. There are, no doubt, many causes of a crime wave and many causes of divorce, and the fact that some circumstance is not common to all of the affirmative instances is no proof that it has no causal relation with any of them. It is, however, a sufficient proof that it is not the cause of all of them.

As a means of discovering new causal relations the joint method contains the same inadequacies that were mentioned in connection with the method of agreement and the method of difference. And like these two methods its chief value is to be found in its use as a means of verifying hypotheses. But with reference to this use it should be pointed out that the strength of the conclusion always depends upon the degree to which one has been able to approximate the exact requirements stated in the canon. Whenever these requirements have been properly met in the problem that is being investigated it is possible to obtain conclusions which are so well established that no successful attack can be made upon them. Examples of this type are furnished by Dr. C. R. Stockard's experiments with guinea-pigs together with the arguments which he used in the interpretation of the same experiments. A brief summary of these will now be given.

THE HEREDITARY TRANSMISSION OF DEGENERACY AND DEFORMITIES BY THE DESCENDANTS OF ALCOHOLIZED MAMMALS

[Based on the report given by Dr. C. R. Stockard in *Cornell University Medical College Publications*, Vol. XI, 1916–17]

In 1910 Dr. Charles R. Stockard of the Cornell University Medical College began a series of experiments for the purpose of determining whether or not it is possible to injure by means of artificial treatment the chromosomes or material carriers of heredity in mammals so that the injury will be apparent in subsequent generations of offspring. The doctrine that he wished to test was the generally accepted one according to which the germ cells which give rise to the new organisms are so segregated from the rest of the body that it is impossible to affect them in any way through external treatment. For his experiments Dr. Stockard used large numbers of guinea-pigs. Many of these animals were systematically poisoned with alcohol and the offspring produced by the alcoholized guinea-pigs were compared with the offspring obtained from normal healthy animals. After the experiments had been carried on over a period of more than five and one-half years he believed that he had acquired enough data for drawing final conclusions. His own report is as follows:

> Is it possible to produce such a racial degeneracy artificially by treating only one generation of the animals and by so doing observe a pathological behavior of the carriers of heredity? Arguing from analogy, there must be pathological heredity due to diseased or altered chromosomes in the germ cells just as truly as there is a known pathological behavior of every other organ and tissue of the animal body.

It becomes then a problem to study the possible methods of modifying the chromosomes or carriers of the inherited qualities of organisms in order further to analyze their normal physiological behavior in the same way that experimental embryology has been able to supply so many valuable clues to the normal processes of development.

In the following pages we believe the facts indicate that individual guinea-pigs are now living in this experiment that had the carriers of hereditary qualities, the chromatin, of their germ cells injured for a longer time than five years. And during this time they have given rise to offspring of more or less degenerate or deformed type, and in some cases these offspring have passed this modified chromatin on through three generations all of which contain pathological chromatin and show some somatic defects and deformities as an index of their tainted chromatic ancestry. Modified chromatin has been living in the experiment for more than five years in six different generations of animals as a result of the alcohol treatment on the one original P_1, parent generation.

We have tried to regulate every controllable source of error, and there can be no doubt that the conditions are brought about in the way described. Could the degeneracy which is so pronounced have previously existed in the stock? This question has been controlled in the first place by the use of two entirely different stocks from different sources and obtained one and one-half years apart. The responses of the two stocks to the experimental treatment have been identical. As a second mode of control every animal has been tested by one or more matings before being introduced into the experiment, and only those giving normally strong offspring have been used.

A further crucial control is the constant mating of normal untreated animals from both stocks under identical cage conditions with the experimental individuals. These animals continue to breed normally until very old, when they gradually become sterile. But none has ever given rise to a defective or deformed individual, and the rate of mortality of the young indicates the average healthy condition formed in the normal guinea-pig breeding. There is a striking contrast between the records of these normal young and the mortality record, the frequency of easily recognized symptoms of degeneracy, and the prevalence of gross deformities in the experimental alcohol races.

The external as well as the internal factors are to be considered not only in individual or embryonic development, but also in heredity. And the present experiments now demonstrate for mammals that either the spermatozoon or the ovum may be experimentally injured or modified by alcohol in such a manner as not only to give rise to subnormal development in the resulting embryo, but also to transmit the effects of the injury from generation to generation, until an affected line actually fades out through degeneracy and sterility as a result of the transmitted condition.

At the beginning of the experiments alcohol was given along with the food, but the animals ate less and the food usually disagreed with them. It was then administered in diluted form by a stomach tube; this method was even more unsuccessful, disturbing digestion and seeming to upset the animals considerably. It is certain that alcohol given to animals through the stomach deranges their appetite and digestion to such an extent that the experimenter is unable to determine whether the resulting effects are due to the alcohol, as such, or to the generally deranged metabolism of the animal. When given in drinking water, they take little or none of the water and the treatment is insufficient.

For these reasons an inhalation method of treatment was resorted to early in the study, and, as far as experience goes, it has no serious disadvantages and does not complicate the conditions of the experiment. A fume tank made of copper was made of sufficient size to supply breathing space for four or five guinea-pigs at one time. The tank has four outlets, so that a definite amount of fumes may be passed through it in a given time and the ventilation controlled. In this way each animal could be given a definite measured dose. The individuals, however, differ so much in their resistance to the treatment that it was found better to treat all to about the same degree of intoxication. Such a physiological index is more reliable, since every animal may be affected to the same degree each day. For this purpose the animals were placed in the fume tank on a wire screen, so that they inhaled the alcohol fumes arising from the cotton to saturate the atmosphere of the tank.

To avoid handling the females during pregnancy, special treating cages were devised. An ordinary box run with a covered nest in which the animal lives was connected by a drop door with a metal-lined tank having a similar screen arrangement to that of the general tank. The pregnant animals could be daily driven into the tank and thus treated with alcoholic fumes throughout the period of pregnancy without being handled in any way that might disturb the developing fetus.

The records of the matings of the alcoholized animals in various pairs, the control or normal matings, and the matings of the F_1 and F_2 generations, that is, the children and grandchildren of the alcoholized individuals, are summarized in the following general table. The table shows the records of 887 matings that produced 1,115 full-term young and 228 early abortions or negative results. These numbers are now of considerable magnitude in spite of the fact that the experiment has been conducted on mammals which produce only small litters and breed slowly as compared with lower animal forms.

EFFECTS OF ALCOHOL ON THE DESCENDANTS OF TREATED MAMMALS

Condition of animals used	No. of matings	Negative results	Still-born litters	No. of still-born	Living litters	Dead soon after birth	Total dead	Surviving young
1. Alcoholic males, normal females....	95	38	10	20	47	39	59	52
2. Normal males, alcoholic females....	43	11	7	20	25	26	46	26
3. Alcoholic males, alcoholic females..	42	20	4	8	18	12	20	15
4. Summary.........	180	69	21	48	90	77	125	93
5. Normal males, normal females....	123	26	2	8	95	24	32	154
6. Treated during pregnancy........	4	0	0	0	4	1	1	7
7. 2nd gen. males, normal females....	55	13	3	28	39	31	39	35
8. 2nd gen. males, alcoholic females..	57	16	9	22	32	25	47	31
9. 2nd gen. males, 2nd gen. females..	111	34	8	18	89	46	64	70
10. 3rd gen. males, 3rd gen. females...	62	23	77	114	32	31	45	23

Explanation of the Chart

The condition of the animals used in the experiments is reported in the first vertical column at the left of the chart. Thus the first horizontal line gives a record of the results obtained by mating alcoholized males with normal females; the second line the results obtained by mating normal males with alcoholized females, etc. Line five represents the control group, or in other words the results obtained from normal animals that had not been subjected to any alcoholic treatment. Line six is concerned with the animals that were treated only during the period of pregnancy. Lines nine and ten report the results obtained from descendants of the alcoholized animals, but the animals were not themselves subjected to the alcoholic treatment.

The fourth generation animals referred to in the tenth horizontal line were particularly defective. Thirty-two living litters were produced, containing in all 54 young; thirty-one of these, almost 60 per cent, died soon after birth, and only 23 survived. It should be added further that six of the 31 that died were paralyzed and unable to stand, while 8 of them were grossly deformed. Six had one or both eyes deformed and two were anophthalmic monsters, being completely without eyeballs, optic nerves, optic chiasma, or any gross signs of optic tracts. The 23 living animals were all weak and degenerate and almost completely sterile. It thus appears that the alcoholic race fades out in the fourth generation while normal control lines from the same original stocks have passed far beyond this generation without showing any signs of degeneracy.

The second vertical line of the chart reports the number of matings in each instance. The third line gives the number of negative results which includes early abortions and failure of the animals to conceive. The next two lines are concerned with the still-born, or animals that were dead at the time of birth. The last vertical line or the one at the extreme right of the chart reports the number of animals that survived, while the preceding one gives the total number of dead animals, including those that were born dead and the ones that died soon after birth.

The horizontal lines of the chart give specific information concerning the animals produced by the various mating combinations. A comparison of the total number of dead animals with the number of those that survived is of particular interest. In addition to the data given in the chart Dr. Stockard reports that nearly all of the offspring of the alcoholized animals were very excitable, nervous animals. Many of them were paralyzed and some showed gross deformities of the eyes. No such conditions were found among any of the offspring of normal animals bred under identical conditions.

Notes on Dr. Stockard's Experiments

Dr. Stockard's experiments with the guinea-pigs are particularly instructive from the point of view of logic inasmuch as they illustrate the way in which a scientist controls the conditions of an experiment, the use of logical methods, and precision with reference to the conclusion that is finally reached. The predominant factor, however, from the standpoint of logic, is the use of the joint method of agreement and difference. Through a careful control of conditions, Dr. Stockard was able to meet adequately the requirements for the joint method and hence the conclusions which he reached were so well established that they could not be successfully attacked. The logical issues involved in the investigation may be summarized as follows:

1. *The conditions of the experiment*

It was essential for this investigation that the guinea-pigs used should be normal healthy animals, capable of producing healthy offspring. That the animals used were of this type was proved by the following:

(a) They were selected at different times from two different stocks. The negative use of the method of difference is employed here. Since the animals were selected from two stocks, the possibility that any defect which might have been present in one group would also be present in the other group was very slight.

(b) The animals were mated prior to the time when they were used in the experiment. Since these matings produced only normal healthy offspring a further proof was obtained that the stock used was free of defects. This point is illustrative of the negative use of the method of difference.

(c) A series of controls were maintained throughout the experiment. Normal animals, not subjected to any alcoholic treatment, were mated and the results of these matings compared with the results obtained from the matings of the alcoholized animals. This procedure involved a use of the joint method of agreement and difference.

(d) The combined results of the three considerations stated above were all in harmony with the hypothesis that the animals used were, prior to the alcohol treatment, free from any defects. Furthermore, the facts mentioned in these three instances could be explained in no other way. Thus a "consilience of results" was used to verify the hypothesis.

It was necessary for the purposes of this investigation that the experimental animals and the control animals be exactly alike except for the alcoholic treatment. Had more than one factor been varied in the comparative study of the two sets of animals, it would have been impossible to obtain a strong conclusion. Hence the following precautions:

(1) The food and cage conditions for the two sets of animals were exactly alike.

(2) Alcoholic fumes were used for administering the poison.

(3) Extra care was taken in the case of the pregnant females.

2. *The use of the joint method of agreement and difference*

(a) The figures given in the first horizontal line of the table indicate the results obtained by mating alcoholized male guinea-pigs with normal untreated males. If these figures are compared with the ones given in line five for the normal or control animals the results presented in the two instances may be interpreted by the joint method. The phenomenon under consideration is a high percentage of defective offspring. The common factor which is present in the first set of instances is the alcoholic treatment. In the second set of instances the phenomenon, viz., a high percentage of defective offspring, is absent and the common factor is the absence of alcoholic treatment. Since the two sets of instances are just alike except for the alcoholic treatment, the conclusion is inescapable that this treatment is the cause of the defects.

Of the animals reported in the first line only the males were treated with the fumes of alcohol. Since the injury was transmitted to the offspring, it follows that the male germ cells must have been affected as there is no other way in which the defects could have been carried. This fact was particularly significant from the point of view of Dr. Stockard's problem.

(b) The second horizontal line indicates the results obtained by mating normal males with alcoholized females. These figures may be compared with those in line one, or with those in line five. In either case it is necessary to use the joint method of agreement and difference. If the comparison is made with the figures in line five, the conclusion follows that the high percentage of defective offspring is due to the alcohol treatment. The evidence does not, however, prove that the injury was transmitted through the germ cells. In this instance the mothers were the treated animals, and hence there were two possible ways through which the defects might have been transmitted. They could have been carried directly through the blood or they could have been transmitted through the maternal germ cells. The latter alternative is at least suggested by the fact that the percentage of defective offspring was approximately the same when the mothers were treated with alcohol as when the fathers were treated. This hypothesis is verified by the results reported in line six.

(c) In the third horizontal line of the table we have the results obtained when both the fathers and the mothers were treated with alcohol. These results when compared with those obtained from the control animals, may be interpreted by the joint method, and the conclusion drawn that the difference in the percentage of defective offspring between the two sets of animals is due to the alcohol. In a similar manner line three may be compared with each of the preceding lines and a conclusion can be reached by using the joint method.

(d) The same logical method may be used to interpret the results recorded in lines four and five. The same conclusion follows in this instance, but, since the numbers are larger, we may say that it is now better established than in any one of the previous arguments.

(e) Line six has a direct bearing on the question of whether or not the germ cells have been affected by the alcohol treatment. The results reported in this line were obtained by treating four normal females with alcoholic fumes during the period of their pregnancy. When these figures are compared with those obtained with reference to the control animals the joint method of agreement and difference yields negative results, thus indicating that the treatment of these animals during pregnancy had no appreciable effect upon the offspring. It is true that the numbers reported in this line are small, and for that reason they cannot constitute a sound basis for generalization. Nevertheless the test was a crucial one, and, if the offspring of guinea-pigs can be affected directly through the blood of the mother during the time when the embryo is being developed, some defects should have appeared in the animals born. With this means of transmitting injury eliminated, the conclusion follows that in the previous examples, the injury was carried through the germ cells.

(f) The seventh horizontal line of the table gives the results obtained by mating the offspring of alcoholic parents with normal individuals. Comparing this record with line six and using again the joint method we obtain the conclusion that the alcohol treatment not only injured the germ cells in the animals treated but injured them in a way that caused defects to appear in subsequent generations.

(g) Lines nine and ten report the results obtained from a large number of *inter se* matings of alcoholic offspring. These animals were not themselves subjected to the alcohol treatment. Except for the fact that they were descendants of treated animals, these groups did not differ from the control animals. One of the groups consisted of second generation descendants and the other group was made up of third generation descendants. In both instances the percentage of defective offspring was considerably higher than for any of the groups which were treated directly with the alcohol fumes. Interpreting these facts by use of the joint method of agreement and difference, the conclusion is unmistakable that the germ cells of second and third generation guinea-pigs were injured by the alcoholic treatment administered to their grandparents or their great-grandparents.

3. *What do these experiments prove?*

In each instance where the joint method was used the conclusion tended to verify the hypothesis that the germ cells of guinea-pigs can be injured in a manner that will be apparent in succeeding generations. These conclusions have in every case been well established. This has been due to the fact that only one factor was varied in the comparison of the two sets of instances. To attack successfully any of the conclusions it would be necessary for one to show that some factor other than the alcohol treatment had been varied and that the injury in question might have been due to that other factor.

Dr. Stockard would not have been able to infer logically, on the basis of these experiments, that the alcohol treatment would have the same effect or even similar effects on any other type of animal. Nor could he state with precision the manner in which the germ cells of the guinea-pigs were affected. At the same time that he was conducting these experiments with guinea-pigs, Dr. Raymond Pearl of Johns Hopkins University was experimenting in a similar manner with white leghorn chickens. Dr. Pearl's results were quite different from those obtained by Dr. Stockard. In other words Dr. Pearl found that the descendants of his alcoholized chickens were healthier than those produced from normal stocks. He concluded that in the case of the chickens the alcohol treatment had acted as a selective agent, destroying the weakened germ cells, but having no effect at all upon the strongest cells. He states that in his opinion the alcoholic treatment acted in the same manner in the case of Dr. Stockard's guinea-pigs.* However, in the case of the guinea-pigs the resistance to alcohol was lower and germ cells were weakened but not wholly destroyed. It was from these weakened cells that the defective offspring were produced. Whether the defects were transmitted in this manner or by some direct qualitative change in the germ plasm it is impossible to say with certainty. But that injuries produced in one generation can be transmitted through the germ cells to succeeding generations is a well established conclusion.

QUESTIONS AND EXERCISES

1. Why would it have been impossible for Dr. Stockard to reach a strong conclusion by using the method of agreement in his experiment with the guinea-pigs?
2. Why could he not have used the method of difference?
3. Show how the difficulties involved in the use of agreement or difference were overcome by use of the joint method.
4. Show how the joint method is a combination of the principle of agreement and the principle of difference.
5. Give an example of the joint method in which the conclusion is weak.
6. Under what conditions does the joint method yield a strong conclusion?
7. How did Dr. Stockard prove that his experimental animals were free from defects? What logical methods did he use?
8. Show how the joint method of agreement and difference could be used to interpret each horizontal line of the table.
9. Why were the results recorded in the first horizontal line of more significance for Dr. Stockard's problem than the results recorded in line two?
10. What was the particular significance of the results recorded in line six?
11. What was proved by the results recorded in lines nine and ten?
12. How did Dr. Raymond Pearl interpret the results of Dr. Stockard's experiments?
13. Is the joint method of agreement and difference adequate for the discovery of causal relations? Give reasons for your answer.

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* Raymond H. Pearl, "The Experimental Modification of Germ Cells," *Journal of Experimental Zoology*, Vol. 22.

14. Show how the joint method was used as an instrument for verification in Dr. Stockard's experiments.
15. To what extent was deductive reasoning employed in Dr. Stockard's total argument?
16. Make a short list of problems which could not be solved by the use of the method of agreement or the method of difference but which could be treated successfully by use of the joint method.
17. Select from your own reading or experience some example of the joint method, describing fully the way in which it was used.

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CHAPTER XV

CONCOMITANT VARIATIONS AND RESIDUES

The Method of Concomitant Variations. The first three of Mill's experimental methods require for their use the elimination of irrelevant circumstances. But it is quite obvious to anyone who is at all familiar with scientific problems that this condition cannot always be fulfilled. There are instances where it is impossible to secure examples which illustrate both the presence and the absence of a given phenomenon without at the same time varying several important factors. Sometimes our only clue, or at any rate our best one, for discovering a causal relation is obtained from a study of phenomena which are present in varying degrees. It is possible under these conditions to observe circumstances which are associated not with the presence and the absence of the phenomenon but with the different degrees or variations of it. It was for the purpose of dealing with instances of this type that the method of concomitant variations was devised.

The canon or rule for its use is as follows: *Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation.** The corresponding variations of the two phenomena may be either direct or inverse, that is, an increase of the one may be accompanied by an increase of the other, or, when one phenomenon has been increased there may be a corresponding decrease in the other one. The essential factor in either case is that the ratio of the corresponding variations shall be constant.

Examples of this method may be seen in each of the following instances. Count Rumford, whose name is always associated with the development of the modern theory of heat, conceived the idea that heat and friction might be causally related. He then performed an experiment for the purpose of testing this hypothesis. He found that whenever friction was applied to certain metals there was always an increase in the amount of heat. If an added amount of friction was used, the result was always an increase in the amount of heat. Thus the method of concomitant variations was used to verify his hypothesis.

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* J. S. Mill, *A System of Logic,* Vol. I, p. 464.

Again, this method has frequently been used to prove that there is a causal relation between sunlight and the growth of plants. Observers have found that plants such as potato tubers, buckwheat, vetch seedlings, and bean plants make only a slight growth in a given period of time if they are freely exposed to the rays of the sun. The same plants if kept in the shade will make a greater growth during the same period, and if kept in a dark place they will make an even greater growth. A further illustration of the method of concomitant variations may be seen in the case of Boyle's law. It was observed that the volume of a gas diminishes when the pressure is increased. Experiments were then performed to determine the exact relation of pressure and volume. These experiments proved that under a given temperature which remains constant the volume of a mass of gas varies inversely with the pressure acting upon it.

These examples show clearly enough that concomitant variations is in many instances a useful instrument for verifying hypotheses. But one must be careful not to claim too much for the method. It is possible to find phenomena which vary in a corresponding manner and yet are not related in a causal way. For example, an attempt was made to explain the dark skin of the negro by attributing it to the direct action of the sun's rays. An observer who was traveling in the region of the Nile River noticed that the farther he went toward the equator the more dark skinned were the natives. Since those who lived nearest the equator were exposed most directly to the sun's rays, he reasoned that this was the cause of the increased amount of pigmentation in their skins. This was a case in which the two phenomena mentioned were found to vary in a corresponding manner; and while it is not impossible that in this particular instance there was a causal relation between them, there are good reasons for believing that a further explanation is necessary.

Another example in which this method yields a weak conclusion may be seen in Jevons' argument concerning business cycles and spots on the sun. He observed that business conditions if viewed over a long period of years have a tendency to go in cycles. This means that business passes through the stages of prosperity, depression, and panic at more or less regular intervals. It has been known for a long time that sun-spots appear in cycles. After reaching a minimum they are gradually increased until at the end of a cycle, which is approximately ten years in length, they reach their maximum. After this they begin to diminish and the cyle is repeated. Jevons noticed a correspondence between the length of the sun-spot cycle and the time required for the three stages of the business cycle. Here were two phenomena so related that a variation in the one was accompanied by a corresponding variation in the other. On this basis he concluded that the two were causally related. But his conclusion is not accepted at the present time as a true explanation of business cycles since neither astronomers nor economists see any reason for believing that either of these phenomena is at all dependent upon the other.

But if concomitant variations is no guarantee of the existence of a causal relation we may well raise the question, "Of what value or use is this method?" The answer is that two definite purposes are met by it. The first of these may be called its negative aspect or purpose. If a variation of a certain phenomenon is not accompanied by a corresponding variation of another given phenomenon, then we may conclude that these two are not related in a causal way. The second value of the method is to be found in its usefulness as a means of suggesting hypotheses.

This value is most evident in the field of the social sciences. For example, if one wishes to discover the social factors that have a tendency to produce crime he may begin by noting carefully the variations in percentage of criminal population over a period of years. The next step will be that of finding other factors which varied in a similar manner over the same period of years. Those factors whose variations correspond most closely to the ones for criminal percentage may then be considered as probable causes. Through the use of other methods of reasoning irrelevant factors may be eliminated and the true cause or causes finally determined. This type of procedure usually involves the use of statistical methods and care should be exercised in order to avoid the fallacies which frequently characterize their use.

AN EXAMPLE OF CONCOMITANT VARIATIONS

[Adapted from Agnes Clerke, *History of Astronomy in the Nineteenth Century*, published by A. and C. Black, London, 1893, pp. 155-158]

In the year 1826, Heinrich Schwabe of Dessau, Germany, obtained a small telescope and began making observations of the sun. This field of research was suggested to him by his friend Harding of Göttingen. The choice which he made proved later to be a very fortunate one. At that time the changes visible on the surface of the sun were regarded as no less capricious than the changes in the skies of our temperate regions. Consequently, the observing and recording of sun-spots was a task hardly more inviting to an astronomer than the reckoning and recording of summer clouds. Leading astronomers were unanimous in their opinion that not even a trace of regularity could be detected in their appearance or their effacements. Even Herschel, who had made a careful study of them until he had become convinced of their importance as symptoms of solar activity, saw no reason to believe that their abundance or scarcity were subject to any orderly alternation.

Schwabe himself did not anticipate the results which he achieved. He compared his fortune to that of Saul, who, seeking his father's asses, found a kingdom. The hope which really inspired his efforts lay in a different direction. He was trying to locate an intramercurial planet whose existence he believed possible, and which he thought would sooner or later cross the face of the sun. He took however the most effectual measures to secure whatever new knowledge might be accessible. During forty-three years his "imperturbable telescope" never failed to bring in its daily report as to how many, or if any, spots were visible on the sun's disc ; the information obtained was recorded day by day on a simple and unvarying system. In 1843 he made his first announcement of a probable decennial period. This announcement failed to attract any general attention. Schwabe worked on, gathering each year fresh evidence of a law such as he had indicated ; and when Humboldt published in 1851 a table of the sun-spot statistics collected by Schwabe from 1836 downwards, the strength of his case was perceived with surprise ; the reality and importance of the discovery were simultaneously recognized, and the persevering observer found himself famous among astronomers.

Meanwhile, an investigation of a wholly different character, and carried on by totally different means, had led forward to a very similar conclusion. Two years after Schwabe began his observations, a movement was inaugurated at a Scientific Congress held in Berlin for studying simultaneously in different parts of the world the complex problem of terrestrial magnetism. For the purpose of carrying on this work a magnetic observatory was established at Göttingen and this place became the centre of the movement.

In September 1851, Dr. John Lamont, director of the Munich observatory, in reviewing the magnetic observations made at Göttingen and Munich from 1835 to 1850, perceived with some surprise that they gave unmistakable indications of a period which he estimated at ten and one-third years. The manner in which this periodicity manifested itself was as follows :

The observations in question referred to what is known as the "declination" of the magnetic needle — that is, to the position assumed by it with reference to the points of the compass when moving freely in a horizontal plane. This position is subject to a small daily fluctuation, attaining its maximum towards the east about 8 a.m., and its maximum towards the west shortly before 2 p.m. In other words, the direction of the needle approaches nearest to the true north some four hours before noon, and departs farthest from it between one and two hours after noon. It was the range of this daily variation that Lamont found to increase and diminish once in every ten and one-third years.

In the following year, Sir Edward Sabine, ignorant as yet of Lamont's conclusions, undertook to examine a totally different set of observations. The materials in his hands had been collected at the British colonial stations of Toronto and Hobarton from 1843 to 1848, and had reference to the spasmodic vibrations associated with terrestrial magnetism. It was for the purpose of learning something concerning the laws that govern these manifestations that the movement inaugurated at the Scientific Congress in Berlin was begun. Once in about ten years these magnetic disturbances sometimes called "storms" were perceived to reach a maximum of violence and frequency. Sabine was the first to notice the coincidence between this unlooked-for result and Schwabe's sun-spot period. He showed that so far as observation had yet gone, the two cycles of change agreed perfectly both in duration and phase, maximum corresponding to maximum, minimum to minimum. What the nature of the connection could be that bound together by a common law effects so dissimilar as the rents in the luminous garment of the sun, and the swayings to and fro of the magnetic needle, was, and still remains, beyond the reach of well-founded conjecture; but the fact was from the first undeniable.

Notes on the Argument Concerning Sun-spots

A. The interpretation of Schwabe's sun-spot records, the similar interpretation of Dr. Lamont's findings concerning magnetic disturbances, and the conclusion that these two sets of phenomena are causally related are illustrative not only of the method of concomitant variations but of the way in which the inductive methods are related to the other elements of the reasoning process. The scientific imagination is evident at each of the following points:

(1) Schwabe did not begin his observations of sun-spots without some definite hypothesis in mind. He was looking for an intramercurial planet whose existence he hoped to be able to demonstrate. This hypothesis defined for him the factors that were relevant and thus served to guide his investigations.

(2) Though failing to find any evidence of the existence of the planet for which he was searching, he continued his observations and kept accurate records of all his findings. In due time the cyclic character of the sun-spot appearances became evident and this gave rise to a new hypothesis concerning the order and regularity of all sun-spot appearances. It was this factor that gave a new direction to his observations.

(3) Dr. Lamont's observations with reference to magnetic disturbances were guided by the suggestions presented at a meeting of the Scientific Congress in Berlin. He was looking for some evidence of regularity in these strange manifestations. From this point he

advanced to the more definite hypothesis concerning the ten and one-third year cycle.

(4) Sir Edward Sabine's hypothesis was suggested by the coincidence of the two cycles.

B. Deductive reasoning was employed in working out the implications of each of the above hypotheses. Schwabe reasoned that if there was an intramercurial planet its path across the face of the sun could be detected with the aid of a telescope. Again, if his hypothesis concerning the periodicity of the sun-spots were true, it would follow that future observations would reveal the same regularity in their appearances. A similar deduction was of course necessary in the case of Lamont's hypothesis and also for the one given by Sir Edward Sabine.

C. The verification of these hypotheses was accomplished through the use of inductive methods as follows:

(1) The method of agreement was employed to explain the regular variations in the number of sun-spots. In this case the length of the cycle constituted the common factor present in all the instances and for this reason it was said to be causally related to the phenomenon.

(2) The same method was used with similar results in the case of the magnetic disturbances.

(3) That the appearance of sun-spots and the occurrence of magnetic storms are causally related was determined by the method of concomitant variations. A variation of one phenomenon was invariably associated with a corresponding variation in the other.

The Method of Residues. The search for causal relations is often complicated by the fact that certain circumstances which are sufficient to explain a part of a given phenomenon are not adequate for the explanation of the entire phenomenon. The invariable antecedents of the thing that is being investigated may be of such a nature that only part of them are brought to light by the methods used. The method of difference may reveal circumstances that are true causes in the sense that the phenomenon will not occur in their absence. Yet at the same time it may be necessary to discover additional factors before a complete account of the cause in question can be known. The method of residues was devised by Mill for dealing with problems of this kind. The canon for the method is as follows: *Subduct* *from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.**

An example of this method may be seen in the very simple process of weighing coal when it is delivered by truck. The truck with its entire load is driven on the scales and the gross weight is recorded. After the coal has been unloaded the empty truck is again driven on the scales and its weight is recorded. The difference in the two recorded weights is the correct measure of the coal that has been delivered. In this instance the residual phenomenon is known, of course, and the only problem that remains is that of making some quantitative measurement of it. But in other cases where the problem is a more complicated one the nature of the residual phenomenon may be unknown and hence a search for its cause or causes becomes necessary.

The attempt to find an explanation for phenomena of this kind has led to many important scientific discoveries. Some of these are used by Mill to illustrate the method of residues. One of his examples is that of M. Arago's experiments with reference to the subject of magnetism. It had been observed by this scientist that a magnetic needle, if suspended by a silk thread and set in vibration, will come to a state of rest sooner if placed over a plate of copper than if no such plate is beneath it. Two causes could be given at once for the needle coming to its state of rest. One of these was the resistance of the air and the other was a lack of perfect mobility in the silk thread. The exact effect of these two causes was determined by experiments made in the absence of the copper. But when these had been allowed for and subducted it was seen that a residual phenomenon still remained and was in some way directly connected with the presence of the copper plate. Further study of this remaining factor led to knowledge of a whole set of new relations.

Again the method of residues was used in the discovery of the element known as "argon." By comparing atmosphere nitrogen with chemical nitrogen it was observed that the nitrogen which is obtained from the atmosphere through a process of eliminating impurities such as moisture, oxygen, etc., possesses a greater density than the nitrogen which is produced chemically from nitric oxide, etc. Investigation of this residual density led to the discovery of argon. Once more this method was used by the Danish astronomer Römer in a study which led to the discovery of the velocity of light. He had made a series of careful observations on the eclipses of Jupiter's satellites. Each of these satellites as it revolves around the planet disappears behind Jupiter and is hidden from the view of observers on earth. Knowing the periodic time of these satellites, Römer had made predictions concerning the exact times when these eclipses should occur. He found, however, that the observed times of these eclipses did not coincide with the times which he had calculated. Here was a residual phenomenon to be explained. The only hypothesis which seemed adequate to account for the facts was that of a definite speed for the propagation of light.

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* J. S. Mill, *A System of Logic,* Vol. I, p. 460.

Later experiments and observations proved that this hypothesis was correct. A classical example of the method of residues and one that has been frequently used for the purpose of illustration is furnished by the discovery of the planet Neptune. A brief history of this discovery together with an analysis of the reasoning involved will now be given.

THE DISCOVERY OF THE PLANET NEPTUNE

[Adapted from Sir Robert Ball, *Great Astronomers*, pp. 340-360]

The movements of the planet Uranus have been carefully observed and recorded ever since the time when that planet was first discovered by William Herschel. After a sufficient number of these observations had been made, the course or route which the newly-discovered body pursued through the heavens was ascertained by those calculations with which astronomers are familiar. It happens that Uranus, which is a planet, possesses a superficial resemblance to a fixed star. Indeed the resemblance is so often deceptive that long before its detection as a planet by Herschel it had been observed time after time by astronomers who believed they were looking at a fixed star. From these early observations it was possible to determine the track of Uranus, and it was observed that the great planet takes a period of no less than eighty-four years to accomplish a circuit. Calculations had been made of the shape of the orbit before the discovery by Herschel, and these were compared with the orbit which observations showed the same body to pursue in those years after its planetary character was known. It could not, of course, be expected that the orbit should remain unaltered ; the fact that the great planets Jupiter and Saturn revolve in the vicinity of Uranus must necessarily imply that the orbit of the latter undergoes considerable changes. When, however, due allowance has been made for whatever influence the attraction of Jupiter and Saturn, and we may add of the earth and all the other planets, could possibly produce, the movements of Uranus were still inexplicable. It was obvious that there must be some other influence at work besides that which could be attributed to the planets already known.

Astronomers could recognize only one solution of such a difficulty. It was impossible to doubt that some other planet existed in addition to the bodies known at that time, and that the perturbations of Uranus, hitherto unaccounted for, were due to the disturbances caused by the action of this unknown planet. Le Verrier, a French mathematician, was urged to undertake the problem of searching for this body whose theoretical existence seemed demonstrated. But the difficulties attendant upon a search of this kind were perhaps greater than any which astronomers had experienced before. It seemed reasonable to suppose that the unknown planet was a very large body with a mass far exceeding that of the earth. It could be shown, further, that a body capable of producing the disturbances in question must revolve in an orbit lying outside the path of Uranus. Hence the new planet must be so far distant from the earth that it could be observed only with the aid of a telescope.

There are in the heavens many hundreds of thousands of stars, and the problem of identifying the planet if it should lie among these stars seemed a very difficult and complex matter. To identify the planet among the stars everywhere in the sky would be almost impossible. If, however, some method could be devised for localizing that precise region in which the planet's existence might be presumed, then the search could be undertaken with some prospect of success. To a certain extent the problem of localizing the region on the sky in which the planet might be expected admitted of an immediate limitation. It is known that all of the great planets confine their movements to a certain zone round the heavens. This zone extends some way on either side of that line called the ecliptic in which the earth pursues its journey round the sun. It was therefore to be inferred that the new planet need not be sought for outside this zone.

It was accordingly suggested to Le Verrier that he should endeavor to discern in what particular part of the strip of the celestial sphere thus indicated the search for the unknown planet should be instituted. The materials available to the mathematician were to be derived solely from the discrepancies between the calculated places in which Uranus should be found, taking into account the known causes of disturbance, and the actual place in which observation had shown the planet to exist. The mathematical procedure used by Le Verrier in the solution of this problem is too complex to be included in an elementary account of his work. However, it is possible to indicate in a general way the method which he followed.

Let us suppose that a planet is revolving outside Uranus, at a distance which is suggested by the several distances at which the other planets are dispersed around the sun. Let us assume that the outer planet has started on its course, in a prescribed path, and that it has a certain mass. It will of course disturb the motion of Uranus, and in consequence of that disturbance Uranus will follow a path the nature of which can be determined by calculation. It will however generally be found that the path so ascertained does not tally with the actual path which observations have indicated for Uranus. This demonstrates that the assumed circumstances of the unknown planet must be in some respects erroneous, and the astronomer commences afresh with an amended orbit. At last, after many trials, Le Verrier ascertained that by assuming a certain size, shape and position for the unknown planet's orbit, and a certain value for the mass of the hypothetical body, it would be possible to account for the observed disturbances of Uranus. It accordingly appeared that a planet possessing the mass which he had assigned, and moving in the orbit which his calculations had indicated, must indeed exist though no eye had ever beheld any such body.

Le Verrier did not have the instruments necessary for studying the heavens, nor did he possess the skill of a practical astronomer. He therefore wrote to Dr. Galle of the Observatory at Berlin requesting him to undertake a telescopic search for the new planet in the vicinity which the mathematical calculations had indicated for the position of the planet at that particular time. Le Verrier added that he thought the planet ought to admit of being recognized by the possession of a disc sufficiently definite to mark the distinction between it and the surrounding stars.

It was the 23rd of September 1846 when the request from Le Verrier reached the Berlin Observatory, and the night was clear so that the memorable search was made on the same evening. The investigation was facilitated by the circumstance that a diligent observer had recently compiled elaborate star maps for certain tracks of the heavens lying in a sufficiently wide zone on both sides of the equator. These maps were as yet only partially complete, but it happened that Hora XXI, which included the very spot which Le Verrier's results referred to, had just been issued. Dr. Galle had thus before his eyes a chart of all the stars which were visible in that part of the heavens at the time when the map was made. The advantage of such an assistance to the search could hardly be overestimated. It gave the astronomer another method of recognizing the planet besides that afforded by its visible possession of a disc. For as the planet was a moving body it would not have been in the same place relative to the stars at the time when the map was made as it occupied some years later when the search was being made.

The search to be undertaken consisted in a comparison made point by point between the bodies shown on the map and those stars in the sky which Dr. Galle's telescope revealed. In the course of this comparison it presently appeared that a star-like object of the eighth magnitude, which was quite a conspicuous body in the telescope, was not represented on the map. This at once attracted the attention of the astronomer and raised his hopes that here was indeed the planet. Nor were these hopes destined to be disappointed. It could not be supposed that a star of the eighth magnitude would have been overlooked in the preparation of a chart whereon stars of many lower degrees of brightness were set down. One other supposition was conceivable. It might have been that this suspicious object belonged to the class of variables, for there are many such stars whose brightness fluctuates, and if it had happened that the map was constructed at a time when the star in question had but feeble brilliance, it might have escaped detection.

Fortunately a test was immediately available to decide whether the new object was indeed the long sought for planet. A star remains fixed, but a planet is in motion. No doubt when a planet lies at the distance at which this new planet was believed to be situated, its apparent motion would be so slow that it would not be easy to detect any change in the course of a single night's observation. Dr. Galle, however, addressed himself with much skill to the examination of the place of the new body. Even in the course of the night he thought he detected slight movement, and he awaited with much anxiety the renewal of his observations on subsequent evenings. His suspicions as to the movement of the body were then amply confirmed, and the planetary nature of the new object was thus unmistakably detected.

Notes on the Discovery of Neptune

A. The method of residues was used in the following manner:

(1) The problem in this instance was that of finding an explanation for the observed discrepancy between the calculated orbit for Uranus and the orbit which the planet had actually followed. The calculated orbit had been based upon known principles that were connected with the law of gravitation. However, the only attracting body that had been taken into account was the sun. When it was discovered that the orbit calculated in this manner did not coincide with the actual path traversed by Uranus, an attempt was made to find an hypothesis that would account for the difference between the two orbits. It seemed reasonable to suppose that the planets Jupiter and Saturn, as well as the other bodies included in the solar system, would exert some attractive influence upon Uranus and thus cause it to deviate from the path that had been calculated. Accordingly this hypothesis was used to explain the discrepancy to which reference has been made. Now the attraction of these planets upon Uranus could be determined mathematically, and in this way it was possible to find out whether or not the hypothesis in question was adequate for the solution of the problem. As soon as this was done it became evident that the attraction of the planets in the solar system was sufficient to account for a part of Uranus' deviation from the calculated orbit, but it was not sufficient to account for all of it. Subducting from the entire deviation that part which could be explained by these attractions, there still remained the problem of finding the cause for the rest of the deviation. It was for the purpose of providing this solution that the hypothesis of Neptune's existence was now presented.

(2) A further use of the method of residues may be seen in the procedure followed for finding a hypothetical mass and position for the new body. Assuming a certain size and position it was determined to what extent such a body would pull Uranus from its course. Deducting this result from the actual deviation to be accounted for, it was possible to modify the position and size of the hypothetical body until the exact course of the planet would be explained by it.

B. Deductive reasoning constituted an important part of the procedure involved in the discovery of Neptune. It was used in dealing with each of the following points:

(1) The implications of the hypothesis that the attraction of Jupiter, Saturn, and the other planets of the solar system were the cause of the deviations of Uranus' orbit were brought to light by means of deduction. This deduction consisted of the mathematical calculations concerning the amount of these attractions.

(2) Finding an hypothesis concerning the size and location of the unknown planet was accomplished in part by deductive reasoning. Assuming a particular size and position for the new body they would proceed to determine the extent to which such a body would cause Uranus to swerve from its regular course. These deductions would then be compared with the actual positions of Uranus, and in this manner the reasoning was conducted until a satisfactory hypothesis was obtained.

(3) Deduction was used again in determining which part of the heavens should be searched with the telescope. Since all the great planets were located within a particular region known as the Zodiac, and since this body for which they were looking was to be numbered among the planets, the conclusion naturally followed that it too should be located within the same area.

(4) Proof that the newly discovered body was a planet rather than a fixed star was again accomplished through deduction. If the body in question were really a planet it would be possible to see its disc and its location would have changed from the position indicated on the map which Dr. Galle possessed. These conditions were shown to be in harmony with facts and thus the hypothesis was verified.

QUESTIONS AND EXERCISES

1. State the canon for the method of concomitant variations and give a concrete illustration of its use. Why is this method frequently employed in the fields of economics and sociology?
2. Discuss the relationship of the method of concomitant variations and the use of statistics. How may causal relations be suggested through the use of concomitant variations?
3. When does this method yield a strong conclusion? Give examples of the use of this method in which the conclusions are weak.
4. What two definite purposes are met by the method of concomitant variations?

5. Show how the method of concomitant variations was employed in the argument concerning sun-spots and magnetic storms.
6. Discuss the relationship of inductive and deductive reasoning in the argument referred to above.
7. Describe the method of residues showing how it differs from each one of the other experimental methods.
8. State the canon for the method of residues and give a concrete illustration of its use.
9. Mention several important discoveries that have been brought about in part through the use of the method of residues.
10. Show how the method of residues was used in the discovery of the planet Neptune.
11. Describe briefly some problem in the field of economics or of sociology and show how the method of concomitant variations could be used in the solution of it.
12. Make a list of examples in which the method of concomitant variations has been used for the verification of some hypothesis.
13. Make a list of examples to illustrate the use of the method of residues.
14. Write an account of some problem in connection with which you would employ the method of residues.

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CHAPTER XVI

ANALOGY AND THE COMBINED METHOD

In addition to the method of sampling and the five experimental methods which we have discussed in previous chapters, there are two more methods which should be considered in order to make our account of the inductive methods complete. These are known respectively as the method of analogy and the combined or inducto-deductive method. They are frequently classified as explanatory methods, a term used to distinguish them from the method of sampling and the experimental methods. This classification is not, however, entirely satisfactory, since it is true that all of the inductive methods are explanatory to some degree.

As we have noted before, the distinction between description and explanation is not an absolute one and for this reason we cannot say that any particular methods are used exclusively for purposes of explanation. We have seen that analogy is frequently employed in the development of the scientific imagination, and without some definite hypothesis in mind it is impossible to use any of the experimental methods. Hence some use of analogy will generally occur in connection with any one of the inductive methods. The combined method is used to some extent whenever an attempt is made to verify an hypothesis. It is not a purely inductive method, inasmuch as its use necessarily includes the process of deduction.

What then is the justification for treating these two types of procedure as separate and distinct from the rest of the inductive methods? Our answer is that the basis of classification which we have used is that of the predominant factor employed in the solution of a given type of problem. There are some instances in which explanations are achieved chiefly through the use of analogy, and other ones in which the chief emphasis is placed upon a working out of the implications of an hypothesis. Hence the inclusion of these two processes as additional explanatory methods.

The Method of Analogy. Analogies are based on resemblances. Two things which resemble each other in certain respects may for that reason be said to be analogous. Thus the planet Mars may be considered as analogous to the Earth since the two bodies resemble each other in so many respects. Relations are analogous when they can be characterized by definite similarities as, for example, the relation of a ruler to his subjects and the similar relation of the captain of a ship to the members of his crew. Plato made use of analogy when in his book called *The Republic* he argued that justice in the life of an individual is similar to justice in the life of the state, for in both instances we have to do with the relation of particular interests to the life of the whole.

Analogy is a very common form or type of thinking. It is usually employed, to some degree at least, whenever a search is made for the solution of any concrete problem. Sometimes the use of analogy does no more than aid in obtaining a description of phenomena, but at other times it leads on to a scientific explanation. It is with the second or explanatory level that we are concerned when we speak of analogy as one of the inductive methods.

The procedure used in the method of analogy may be described as follows. Two things resemble each other in certain respects ; it is therefore inferred that they are of the same type, that is, governed by the same principles or laws ; hence what is true of the one will also be true of the other. For example, scientists knew that sound travels in waves long before they knew that light travels in a similar manner. They discovered that light the same as sound can be reflected and further that the direction of their reflection obeyed the same law. On the basis of this analogy they concluded that light must also travel in waves. Pasteur, having demonstrated that a certain kind of treatment would make dogs immune to hydrophobia, reasoned by analogy that a similar treatment would render human beings immune to the same disease.

The same method of reasoning has been used to prove that criminal tendencies are inherited. For instance, Carl Rath, after making a careful study of family histories of 98 inmates of a penal institution at Siegburg, Germany, found that the offspring were criminal in a ratio which is fairly close to the Mendelian ratio. Since the Mendelian ratio is known to be a statement concerning characters that are inherited, it was inferred that criminal tendencies which appear in the same ratio are also inherited. Again, the method of analogy is particularly useful in the field of law. As soon as a client presents his case, the lawyer examines a list of similar cases and concludes that the type of decision rendered in these cases will also be obtained in this particular one. Judicial decisions are almost always accompanied by references to analogous cases. Frequently it happens that the strongest argument which can be advanced in support of a position consists in showing the striking similarities between the case at hand and some other case which has already been decided.

Analogical arguments may be either strong or weak. It depends on the similarities of the two things that are compared. In general this rule may be applied whenever the method of analogy is used. If the similarities upon which the argument is based are superficial, the conclusion will be weak; but if the similarities are fundamental to the problem at hand, the conclusion will be strong. This may be illustrated in the following example. Two students in my class come from the same town, they are of the same height, and they both have red hair. Since one of them is known to be a good student, I infer that the other one will also be a good student. Obviously the conclusion of this analogical argument is a worthless one. The reason for this is that the similarities cited have no bearing at all on the question of intelligence. They are superficial resemblances. On the other hand let us suppose that the two students have been given the same intelligence test and that they have both made a high score. On the basis of this similarity I infer that because one of them has been a good student the other one will also do good work. The analogy in this case is a strong one due to the fact that the resemblance is a fundamental one so far as the question of intelligence is concerned.

The validity of any analogical argument can be determined only by an examination of the similarities involved. When it is impossible to say whether or not the similarities are superficial it is necessary to test the conclusion by making deductions from it and comparing these with facts. Unless verification of this kind can be obtained it is unsafe to accept the conclusion that has been reached. It is always possible to find one or more similarities between any two things that are compared, and hence an analogy of some kind can be found to support any conclusion that is desired. In this way weak analogies are often employed to support erroneous conclusions. Francis Bacon once argued that since foreign wars are analogous to the heat of exercise and civil war analogous to the heat of a fever, the former is advantageous and the latter detrimental to the welfare of the state. Psychoanalysts have often interpreted dreams by pointing out some similarity between the dream experience and that which they believe it symbolizes. And in the same way theologians have sometimes used the allegorical method in the interpretation of the Scriptures. These analogies do not permit of any experimental verification and they are quite worthless from the point of view of logic.

The most important use of analogy in relation to the methods of science is to be found in its function as a means of suggesting explanatory hypotheses. New hypotheses are usually the result of a comparison between the problem at hand and similar ones that have been experienced before. Thus, in the case of the typhoid-fever epidemic at Cedar Falls, the hypothesis concerning the public water supply was suggested because in previous epidemics the source of contagion had been found in connection with that factor.

AN EXAMPLE OF THE METHOD OF ANALOGY

Bradford v. Boylston F. & M. Insurance Co.

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Assumpsit on a policy of insurance underwritten by the defendants, upon property of the plaintiffs shipped on board a vessel, from a port in England to a port of discharge in the United States; "partial loss to be computed upon each package as if separately insured." The plaintiffs allege in their declaration, that on May 5, 1828, they shipped on board the *Aspasia*, at Liverpool, certain goods, to be conveyed to New York, and that owing to the tempests on the voyage the salt water found access to the goods and injured them; and the plaintiffs claimed a partial loss amounting to 33 per cent. upon the value of the goods.

At the trial before Wilde, J., it appeared that the goods alleged to have been damaged consisted of thirty-two bales of point and duffil blankets and that the blankets were manufactured for the plaintiffs by one Wood, in the kingdom of Great Britain. The plaintiffs offered evidence tending to prove that the blankets were damaged on board, by the perils alleged in their declaration. The defendants contended that the damage arose from some defect in the manufacture of the blankets, or from their having been fraudulently packed by Wood in a wet state, for the purpose of increasing their weight, the blankets having been purchased by the plaintiffs by weight. The defendants offered in evidence two depositions of one Russell, to prove that during the year 1828 he imported into New York certain bales of point and duffil blankets manufactured by Wood, which proved to be damaged, and, in the opinion of Russell, by being packed in a wet state for the purpose of increasing their weight. The defendants also offered the testimony of one Lee, who stated that in 1828, the firm of which he was a partner, received a consignment of point and duffil blankets from Wood, and also some which they purchased from Wood; that the blankets in the inside of the bales were slightly damp and very much spotted, and the outside blankets were perfectly dry; and that the damage to the blankets exhibited as part of the *Aspasia's* cargo, was of similar character, and he would have supposed that they were part of his own; that the damage was of a peculiar kind and not like that produced by salt water. There was evidence in the case tending to show that the damage was caused by sulphuric acid. To the admission of the depositions of Russell and of the testimony of Lee, the plaintiffs objected, on the ground that it was an attempt to prove that Wood had fraudulently damaged the blankets in question, by proving that he had in other cases damaged the blankets by packing them in a wet state to increase their weight; which the plaintiffs contended it was not competent for the defendants to do. But the Judge overruled the objection and permitted the evidence to go to the jury. . .

The jury found a verdict for the defendants, and no inquiry was made or moved for by the plaintiff's counsel at the time, as to the principles upon which the verdict was founded. The plaintiffs moved for a new trial:

Putnam, J., delivered the opinion of the Court.—The main objection which was made to the proceedings at the trial, is, that the testimony of Lee and the depositions of Russell ought not to have been received for the defendants. It is contended that the evidence proved that Wood made bad blankets for other persons and that this circumstance has no tendency to prove that he made bad blankets for the plaintiffs; that it is no better than to offer evidence of general bad reputation, when a party is called upon to prove a particular fraud. And the case of Holcombe v. Hewson, 2 Camp. 391, has been much relied upon, and is the strongest which we have seen for the plaintiffs. In that case Holcombe was found to have proved that he had supplied Hewson with good beer, and he offered to prove that several other persons who dealt with him while he supplied the defendant, were satisfied with his beer, as being of excellent quality; but Lord Ellenborough held the evidence to be inadmissible, because he might have dealt well with some, but not well with other customers. This case was properly decided; the evidence offered by the plaintiff was of his own doings and conduct in regard to strangers, from which it was intended to be inferred that his conduct towards the defendant had been similar; that would clearly be a *non sequitur*.

But in the case at bar the evidence objected to does not arise between the party who furnished the damaged goods and the purchaser, but between strangers to the manufacturer. The evidence comes in collaterally, and is greatly, if not unavoidably, connected with other testimony which is admitted to be material and competent. The point to be proved by the defendant was, that the blankets were injured by some other cause than the perils of the sea. They had a peculiar appearance; they were so singularly spotted and marked, that Lee, who had imported blankets of similar appearance from England, would have supposed they were the same.

This happened in 1828, the same year that the plaintiffs imported those now in question. It happened also that a great many bales of blankets exactly resembling the plaintiffs were imported that year from England into New York. Now it is conceded that it would be perfectly competent to compare the plaintiff's blankets with the other damaged blankets, in order to satisfy the jury that it was not the damage of the sea which operated so peculiarly and injuriously. It is not contended but that it would be proper to prove that they all came from England; but that evidence would be much less satisfactory than to trace them to one manufactory in England. If you may properly go to the manufactory, why not to the name of the manufacturer? It is not easy to draw the line. They are marked and injured as no other imported blankets were. They may have been injured by persons at Wood's manufactory, without his knowledge, and so without any intention of fraud on his part; it may have been done by some enemy, with a view to prejudice Wood in his business. In the case of Holcombe v. Hewson, before cited, Lord Ellenborough said, "Let the plaintiff call those who frequented the defendant's house and drank the beer which he sent in." Why not, in the case at bar, call those who bought of Wood blankets marked in this extraordinary manner at the same time? The object is not to impute a fraud to the manufacturer (for we do not see any motive he could have to destroy the blankets), but to prove in a suit between other parties that the injury was not caused by the sea. And the evidence that the great number of bales of blankets which came that year, in six ships, from Wood's manufactory, had these distinguishing marks upon them, which are ascertained to have been such as would be occasioned by sulphuric acid, is we think admissible as tending to disprove the allegation of the plaintiffs, that the injury arose from the perils of the sea. . . We are of the opinion that the judgment should be rendered upon the verdict.

Notes on Bradford v. Boylston F. & M. Insurance Company

In this case the particular point to be determined by the court was whether or not the damage of the blankets in question had been caused by the negligence of the transportation company. If it could be proved that the blankets were damaged during the voyage across the ocean or that they were in good condition at the time they were loaded on the ship, the insurance company would be liable for an amount equal to the damage. On the other hand proof that the goods were in a faulty condition at the time they were loaded or that the damage was caused by something other than the sea voyage would relieve the company of that liability. The argument of the plaintiff was based on their use of the method of difference. Assuming that the blankets were in a good condition at the time they left Liverpool and knowing that they were damaged when they arrived in New York, they reached the conclusion that the injury to the goods had been caused by the sea-voyage. The defendants then proceeded to break down this argument by showing that one of the assumptions on which it was based was untrue. The predominant method of reasoning which they employed was analogy. Examples of this method may be seen in each of the following instances:

(1) The testimony of Russell. He had purchased blankets from the same manufacturer, and on their arrival in New York they were found to be damaged. Furthermore the damage in this instance was of the same kind as that in the case of the plaintiff. Obviously the two cases were similar in several essential respects. Russell stated that in his opinion the damage was caused by the blankets having been loaded while they were in a faulty condition. Since they were purchased by weight there would be some object in loading them while they were wet.

(2) The testimony of Lee was the basis for a stronger analogy. The case which he described contained all the similarities mentioned in the testimony of Russell, and in addition he offered proof that his blankets were not damaged by the sea voyage. His proof consisted in a recitation of the following points:

(a) His blankets were dry on the outside of the bales, but on the inside they were damp and spotted.
(b) The damage was not like that which would have been produced by contact with salt water.
(c) There were evidences of damage by sulphuric acid.

These facts indicated clearly enough that the damage in this case had not been due to the negligence of the transportation company. And since the case at bar was analogous to this one in all essential respects, it followed that the same conclusion would obtain with reference to it.

(3) In order to invalidate this argument, the plaintiff urged that it was based on testimony that was irrelevant to the point at issue. Why should the court be concerned with the question of the cause of the damage in the case of Lee's blankets? They supported their claim by another analogy. This case they urged was analogous to that of Holcombe v. Hewson. In this instance the judge excluded the testimony which was offered by friends of the defendant on the

ground that it had nothing to do with the case before the court. If testimony should have been excluded in that case it should also be excluded in the case of the damage to the blankets.

(4) In reply to this argument of the plaintiff, the court pointed out the weakness in the analogy on which it was based. The testimony of friends that they had purchased good beer from Holcombe was irrelevant so far as concerns the question of whether or not he sold a poor quality of beer to strangers. But in the case at bar, the testimonies of Russell and Lee did have a direct bearing on the point at issue since the instances which they described were in all essential respects like the one presented by the plaintiff. Here was an important difference between the testimony presented in the beer case and that which was offered in the one concerning the damaged blankets. For this reason the analogy was weak and thus the plaintiff's argument was rendered invalid.

The Combined Method. The second one of the two explanatory methods is known as the *combined method.* This name is used because the method is really a combination of inductive and deductive processes. Some logicians refer to it as the inducto-deductive method. In some instances it is called the method of hypothesis, and in others the complete method of explanation. None of these is entirely satisfactory, and yet each one indicates some characteristic of the method. From one point of view it is not a new nor additional method but rather an account of what takes place in every complete act of problem solving. We have in this text laid particular stress upon the fact that the solution of any problem or the intelligent use of any one of the inductive methods involves first of all a definite hypothesis. From this hypothesis deductions are made and finally observation and experiment are used to see whether or not the deductions correspond with facts.

Now this process includes all of the steps used in the combined method. It would seem, then, that there is nothing to be gained in speaking of this process as a distinct logical method. The justification for so doing lies in the fact that there is a certain type of problem in which the chief emphasis is placed upon the working out by deductive reasoning of the implications of an hypothesis. We have noted before that in the actual experience of thinking there is an overlapping of the logical methods, each one drawing support from and in turn contributing to the strength of others. Hence the classification of methods has been based on the predominant factor involved in each one. Now in this instance we have as the predominant factor the elaboration of hypotheses by the use of deduction, and for this reason we are warranted in speaking of the process as a distinct logical method.

The combined method is often used in those fields where experimentation is impossible. In astronomy, for example, many of the problems which arise can be solved only by accepting as true some hypothesis and comparing the deductions that can be made from it with observed facts. It was by following this type of procedure that the discovery of Neptune was achieved.

The astronomers accepted as true the hypothesis that a planet of a certain size was located at some particular place in the heavens. From this hypothesis they deducted the amount of attractive force the planet would have on the orbit of Uranus, and this deduction was then compared with observed facts. In the same way the English astronomer Halley discovered the comet which now bears his name. Observation of the orbits traversed by comets in the past brought to light the interesting fact that three of these paths were practically identical and further that the comets traversing these orbits had appeared on successive dates which were approximately seventy-five years apart. To explain these appearances Halley proposed the hypothesis of a single comet which completed a definite orbit every seventy-five years. Deductions from this hypothesis indicated that the comet must have appeared at other seventy-five year intervals and that it would appear again when the next interval of that length was completed. These deductions corresponded with actual facts and thus Halley's hypothesis was proved to be correct.

Again this method is useful in the field of ethics. How else could one determine whether or not a given conception of the good is a sound one? It is only by working out the implications of a theory so as to bring to light any inconsistency or disagreement with facts which is implied in it that one can tell whether it is an adequate theory.

Since the hypothesis is one of the most important factors in the use of the combined method, it will be in order to say something concerning the requirements of a good one. It should be pointed out that any hypothesis which does not permit of verification is a worthless one. Such, for example, is the hypothesis in the field of ethics known as psychological hedonism. According to this hypothesis every action on the part of an individual is the result of a single motive which is that of the person's own pleasure. Assuming this hypothesis to be true there is no possibility of ever finding any facts that are not in harmony with it. But any theory or hypothesis which by its own nature is incapable of being proven false, cannot be proved to be true. In other words the hypothesis is one from which it is impossible to make deductions that can be compared with observed facts. It is an unverifiable hypothesis and for that reason a worthless one.

Similar hypotheses are often found in the fields of theology and of metaphysics. Duns Scotus, a medieval philosopher, taught the doctrine of an "inscrutable will of God." But, we may ask, of what use is the hypothesis of God's will if we have no way of finding out what the will of God is? Parmenides, one of the early Greek philosophers, taught that reality is an eternal, unchanging, unmovable One. This was his hypothesis concerning the ultimate nature of the universe. But the difficulty with it lies in the fact that there is no way of determining whether it is true. Since human experiences are capable of revealing to us only that which is appearance or illusion, these cannot be used to verify the hypothesis. These examples are not intended to convey the idea that all the hypotheses of theology or metaphysics are worthless, but rather to point out that this is true of the ones that cannot be verified through human experience.

The only way to verify an hypothesis is to make deductions from it and then compare these deductions with facts. Sometimes a single deduction is sufficient for this purpose. This is true whenever it is possible to secure a crucial test. For instance, if I wish to test the hypothesis that a certain kind of acid will cause a given type of metal to become brittle, all that is necessary is to put a piece of this metal into a jar filled with this acid and observe the result. If the metal becomes brittle the hypothesis is verified. Thus a single deduction and a single experiment is all that is necessary for verification.

Again the English astronomer Halley used a crucial test to verify his hypothesis concerning the comet which bears his name. On the assumption that his hypothesis was true he made the deduction that it would appear again at a certain time. The fact that it did appear at the time predicted proved that his hypothesis was correct. When it is impossible to obtain a crucial test, an hypothesis may be verified by a consilience of results. This means that several deductions will be made from the hypothesis and if these are all in harmony with known facts, and if the hypothesis in question is the only one that is consistent with these facts, it may be regarded as true.

AN EXAMPLE OF THE COMBINED METHOD

Courvoisier's Case

[From *Principles of Judicial Proof,* by J. H. Wigmore. By permission of the author and Little, Brown & Company, publishers]

The facts shown in evidence at Courvoisier's trial were, that Lord William Russell, an old gentleman aged seventy-three, who lived by himself in Norfolk Street with only two female servants and his valet, was found brutally murdered in his bedroom, his throat cut, and the bone at the back of the neck cut through by one desperate blow. The hypothesis of suicide was quite untenable ; it was not only opposed to medical evidence, but no instrument was found, at or near the spot, by which suicide could have been committed. Suspicion early attached to Courvoisier, but it has always been recognized that the evidence was purely circumstantial evidence ; no eye saw the act committed.

The question really at issue, according to the summing up of the Chief Justice, was whether the house was entered from without or whether the robbery was committed by someone of the inmates, who also committed the murder. Was it a genuine robbery, or were valuable articles secreted in the pantry and scullery and marks made on the back area door with the view of diverting the attention of the officers of justice so that the guilty party or parties might escape detection? The hypothesis of burglary derived some prima facie support from the fact that the back area door was found open and certain marks were found on it, and also from the fact that there was a ladder in the yard that would have enabled the burglars to scale the wall of the area yard. The hypothesis of burglary was, however, negatived on what seems very conclusive evidence. Assuming it, it became also necessary to assume that the burglars deliberately selected a difficult mode of access and broke open a door which required considerable force to break through, when they had a much easier access through a glass door. There were no marks on the walls or leads over which, according to the hypothesis of burglary, the burglars must have passed. Yet these leads were covered with dust, which was undisturbed. Finally the Chief Justice asked: "Was it possible to believe, if thieves had entered the house for purposes of plunder, they would have made their exit, leaving so many small but valuable articles behind them, which might so easily have been disposed about their persons?" The hypothesis of burglary and constructive murder seemed highly improbable; but when it was once dismissed, it became essential to conclude, that either Courvoisier, or the two female servants, must have murdered Lord William Russell. Tindal, C. J., directed the jury that no one except the prisoner, the two female servants, and Lord William Russell were in the house that night. The hypothesis that any one might have concealed himself on the premises seems not to have been adverted to, as, presumably, there was not the slightest evidence of it.

The circumstantial evidence against Courvoisier comprised some five facts: (1) He had observed to the female servants, "I wish I had old Billy's money, I would not be long in this country." (2) His agitation and contradictory statements to the police. (3) The discovery of gloves and handkerchiefs in his own portmanteau slightly stained with blood. (4) The secreting of certain valuable articles, including a ten-pound note, all belonging to Lord William Russell, in the scullery and pantry (no stranger, Tindal, C. J., observed to the jury, could think of putting these articles where they were found). (5) At about the date of the murder, Courvoisier called at a place of entertainment (also used as a hotel) in Leicester Square, where he had previously been employed as a waiter, under the name of John, and deposited a brown-paper parcel for safekeeping with a Mrs. Piolane, the wife of the master of the establishment. As Courvoisier was not known in the establishment in Leicester Square under his proper name, at the time the parcel was left, he was not suspected. There seems to be a conflict of evidence whether the parcel was left before or after the murder. It may be assumed that it was left before, this being so, according to Mrs. Piolane's evidence; while her servant, who failed to identify Courvoisier, thought it had been left after the date of the murder. Some six weeks afterwards, during the first day of Courvoisier's trial, Mrs. Piolane was attracted by the suggestion in a paragraph in a French newspaper, in which the crime was discussed, to the effect that the articles taken from Lord William Russell's house, for which a reward of 50 pounds had been offered, might have been deposited in some foreign hotel in London by Courvoisier. The parcel was opened with some ceremony in the presence of three persons, including a solicitor, and an inventory was taken. It was found to contain silver spoons and forks marked with Lord Russell's arms, two pairs of new stockings, a pair of gold auricles, a pair of dirty socks and an old flannel waistcoat. A jacket and tow were wrapped round the things to prevent their rattling. Thomas Davis, formerly in the service of Mr. Webster, an optician, gave evidence at the trial of Courvoisier that he made a pair of gold auricles for Lord Russell similar to those found in the parcel left by the prisoner at the hotel in Leicester Square. John Ellis, his lordship's former valet, recollected that Lord William Russell wore such "ear-instruments." Mr. Molteno, a print-seller in Pall Mall, identified the brown paper in which the spoons and forks were wrapped up as the covering of a print sent from his shop; his own stamped label was on it, and he was in the habit of sending prints to Lord William Russell. Finally, Lydia Banks, a washerwoman, identified the socks as Courvoisier's.

It may be doubted if a more dramatic moment was ever reached in a trial for murder than this discovery of Lord Russell's plate and the identification of Courvoisier as the mysterious bearer of the parcel to the depositary, Mrs. Piolane. The *Times* observed that "the fact of the plate having been discovered, and identity of the prisoner proved, a communication to that effect was made to the prisoner, and on hearing a piece of intelligence so astounding and unexpected he turned deadly pale and became extremely agitated, and before the time arrived for his being again placed at the bar he sent for Mr. C. Phillips, his counsel, and disclosed his guilt to him."

On the night of the fatal occurrence he was in the lower part of the house in the act of secreting the different valuable articles described in the scullery and pantry, where they were found by police. Lord William Russell being taken suddenly ill, came downstairs unexpectedly while he was so employed and caught him in the act and told him he would discharge him from his service. This roused him to a state of madness and he cut his throat with a carving knife. . . It seems impossible to doubt that Courvoisier was the guilty man ; his confession to his counsel on the second day appears to conclude the question.

Notes on Courvoisier's Case

The argument which led to the conviction of Courvoisier is one in which the predominant method of reasoning was that of the combined method. It was employed in each of the following instances.

(1) The hypothesis of suicide. This hypothesis was ruled out because deductions from it, or in other words, the necessary implications of it, were not in agreement with the facts found in connection with the death of Lord William Russell.

(2) The hypothesis that robbers had broken into the house and committed the murder was given careful consideration. This hypothesis seemed, at first, to find support in the fact that the back door had been forced open and a ladder was found in the yard. But further examination of the premises revealed the fact that no marks could be found either on the walls or the floor of the passageway over which the burglars would have had to pass. And this in spite of the fact that these parts of the premises were covered with dust. This fact was inconsistent with the hypothesis of burglars having committed the murder.

(3) The third hypothesis was that the murder had been committed by one of the regular inmates of the house. This meant that the guilty party was either Courvoisier or one of the two female servants. But inasmuch as the evidence seemed to indicate that neither one of the female servants could have committed the crime, the hypothesis of their guilt was set aside until a thorough consideration had been given to Courvoisier's case.

(4) The hypothesis of Courvoisier's guilt was consistent with all of the following facts.

(a) He had remarked to one of the servants, "I wish I had old Billy's money, I would not be long in this country."

(b) His statements to the police contained several contradictions.

(c) Gloves and handkerchiefs found in his portmanteau were stained with blood.

(d) Several valuable articles, including a ten-pound note, were found secreted in the pantry.

(e) The package that was left at the hotel in Leicester Square in London contained articles that had belonged to Lord William Russell and there was sufficient evidence to prove that the package had been deposited by Courvoisier.

When all of these facts were taken into account it was evident not only that they were consistent with the hypothesis of Courvoisier's guilt, but that this hypothesis was the only one by which they could all be explained. The combined evidence constituted a consilience of results which was later verified by the confession which the prisoner made to his attorney.

QUESTIONS AND EXERCISES

1. Show how the methods of analogy and the combined method are related to the other inductive methods that have been considered.
2. What is the justification for treating them as separate methods? Why are they classified as explanatory rather than experimental methods?
3. What is an analogy? Mention several analogies other than the ones described in the text.
4. Describe briefly the procedure of the method of analogy. Does the method of analogy include the use of a universal proposition or is it merely a case of reasoning from particulars to particulars?
5. How is the method of analogy employed in the field of law?
6. When does an analogical argument yield a strong conclusion? What are superficial resemblances?
7. Give examples of your own that illustrate both strong and weak analogies.
8. Explain and illustrate the function of analogy in connection with the formation of scientific hypotheses.
9. In the case of Bradford v. Boylston F. & M. Insurance Co., why did the testimony of Lee constitute a strong analogy?
10. On what basis did the plaintiffs object to the introduction of this testimony? What analogical argument did they present?
11. How did the beer case testimony differ from the blanket case testimony?

12. Explain in brief the procedure of the combined method. Why is it called the combined method? What other names are sometimes given to this method?
13. In what sense is it true that this method contains no new principles? Why is it treated as a separate method?
14. Why is this method used so frequently in the field of astronomy? How is it employed in the field of ethics? How was it used in connection with the discovery of Neptune?
15. What is the essential requirement of a good hypothesis? Mention several hypotheses in which this quality is lacking.
16. How are hypotheses verified? What is a crucial test? Give examples. What is a consilience of results?
17. Why is it sometimes necessary to make many deductions from an hypothesis?
18. Describe the way in which the combined method was used in the conviction of Courvoisier.
19. From your reading of newspapers, attendance at lectures, etc., select a list of arguments in which the method of analogy is used. Determine the validity of the inference in each case.
20. From similar sources make a list of arguments in which the combined method is used.

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PART FOUR
PROBLEMS IN LOGIC

CHAPTER XVII

EXAMPLES OF REASONING FROM THE BIOLOGICAL SCIENCES

I

SPONTANEOUS GENERATION

One of the first men to investigate the supposed phenomenon of spontaneous generation was an Italian named Francesco Redi. He began with a study of the worms found in rotten meat. The generally accepted explanation of these worms was that they had developed spontaneously from the meat. But this assumption Redi proved was untrue. He took some meat, covered it with gauze so that it would be protected from flies and other insects, and left it in a warm place for several days. Flies, attracted by the odor, came and deposited their eggs on the gauze. From these eggs were hatched the worms which until this time had been supposed to begin life spontaneously in the meat itself.

The experiment of Redi proved only that the visible organisms in question did not develop spontaneously. The study of microscopic organisms was carried on about the middle of the eighteenth century by an English priest named Needham, and also by an Italian priest named Spallanzani. Needham believed strongly in the doctrine of spontaneous generation. He had worked with the French scientist Buffon in the study of microscopic animalculae. They were both of the opinion that there is contained in matter a certain productive or vegetative force which is capable of bringing about the formation of various species in the organic world.

According to their view there exists certain primitive and incorruptible parts common to animals and to vegetables. These organic molecules cast themselves into the molds or shapes which constituted different beings. When one of these molds is destroyed by death the organic molecules become free. After working upon the purified matter and assimilating some of the raw material they form by their reunion a multitude of organized bodies. Some of these, such as earthworms and fungi, seem to be fair-sized animals or vegetables but others can be seen only through a microscope. All of these bodies, they believed, existed through spontaneous generation. This process they said was taking place continuously and universally after death and sometimes during life.

In support of this theory of spontaneous generation Needham presented the results obtained from one of his experiments. He had placed some putrescible matter in vases which were closed with cork. These vases were then put on some warm ashes and allowed to remain for some considerable length of time. At the end of this period the vases were opened and found to contain animalculae. Since these organisms were not present when the liquid was placed in the vases he concluded that they must have developed spontaneously.

Spallanzani was not, however, convinced by this experiment. He suspected that Needham's argument was defective at two points. In the first place there was no proof that organisms were entirely absent in the liquid at the time it was put in the vases. It was true that Needham had heated the liquid to a certain degree but the heat used was not sufficient to destroy any life that might have been present. In the second place it would have been easy enough for seeds to have entered the vases after they had been closed since the cork used as stoppers was porous and capable of admitting air to the liquid.

Accordingly, Spallanzani repeated the experiment taking care to remedy both of these defects. He used hermetically sealed vases and kept them in boiling water for a full hour. After a reasonable length of time he opened them but did not find the slightest trace of any animalculae although he examined with a microscope the contents of nineteen different vases. This experiment was sufficient to convince Spallanzani that Needham's vegetative force was only a myth. But Needham did not on this account surrender his position. He retorted that Spallanzani had weakened or perhaps destroyed the vegetative force of the infused substances by leaving his vases in boiling water for an hour. He advised him to try again with less heat. Spallanzani answered this retort by tapping one of the vases gently with a small hammer so as to produce a tiny crack which however was capable of admitting a certain amount of air to the liquid. When this vase was opened shortly afterwards it was found to contain animalculae.

About the middle of the nineteenth century the question of spontaneous generation again became a subject for scientific investigation and debate. In December of 1858, M. Pouchet, director of the Museum of Natural History of Rouen, sent a note to the French Academy of Science in which he declared that he was prepared to demonstrate that plants and animals could be generated in a medium absolutely free from atmospheric air, and in which, therefore, no germ of organic bodies could have been brought by air.

The note attracted the attention of Louis Pasteur and immediately challenged him to thorough study and investigation of the whole question. Pasteur's work on this problem continued over a period of years and included a large amount of experimentation. Some of his experiments were carried on in the region of the Alps mountains. One of the interesting facts brought to light by these experiments was the difference in result when the same experiment would be performed at the base of the mountains and again at a much higher elevation in the top of a mountain. It frequently happened that animalculae would develop at the lower altitudes, but the same liquid under similar conditions would be entirely free from these organisms if the experiment were performed at one of the higher levels. This suggested to Pasteur that the difference in the conditions of the atmosphere at the two levels must in some way be connected with the cause of the living organisms. The chief difference between these two atmospheres seemed to be that dusts were present in one case but not in the other.

Pasteur then began a microscopic study of atmospheric air. He reasoned that if germs are present in ordinary atmosphere it should be possible to arrest some of them as they travel through space. It then occurred to him to draw — through an aspirator — a current of outside air through a tube containing a little plug of cotton wool. The current as it passed deposited on this sort of filter some of the solid corpuscles contained in the air ; the cotton wool often became black with various kinds of dusts. Pasteur assured himself that amongst various detritus those dusts presented spores and germs. He said, "There are therefore in the air some organized corpuscles. Are these germs capable of vegetable productions or infusions ? That is the problem to solve." He undertook a series of experiments to demonstrate that the most putrescible liquid remained pure indefinitely if placed out of the reach of atmospheric dusts. In an address which he delivered before a group of scientists he explained how the dusts which are suspended in air contain germs of inferior organized beings and how a liquid preserved from contact with these germs can be kept indefinitely. These are his own words :

"Here is an infusion of organic matter, as limpid as distilled water, and extremely alterable. It has been prepared today. Tomorrow it will contain animalculae, little infusories, or flakes of mouldiness.

"I place a portion of that infusion in a flask with a long neck, like this one. Suppose I boil the liquid and leave it to cool. After a few days, mouldiness or animalculae will develop in the liquid or against the flask; but that infusion being again in contact with air, it becomes altered, as all infusions do. Now suppose I repeat the experiment, but that, before boiling the liquid, I draw the neck of the flask into a point, leaving its extremity open. This being done, I boil the liquid in the flask; and leave it to cool. Now the liquid of this second flask will remain pure not only for two days, a month, a year, but three or four years — for the experiment I am telling you about is already four years old, and the liquid remains as limpid as distilled water. What difference is there, then, between these two vases? They contain the same liquid, they both contain air, both are open! Why does one decay and the other remain pure? The only difference between them is this: in the first case dusts are suspended in the air and their germs can fall into the neck of the flask and arrive in contact with the liquid, where they find appropriate food and develop; thence microscopic beings. In the second flask, on the contrary, it is impossible, or at least extremely difficult, unless air is violently shaken, that dusts suspended in air should enter the vase; they fall on its curved neck. When air goes in and out of the vase through diffusions or variations of temperature, the latter never being sudden, the air comes in slowly enough to drop the dusts and germs that it carries at the opening of the neck or in the first curves. The germs do not reach the liquid in the vase.

"This experiment is full of instruction; for this must be noted that everything in air save its dusts can easily enter the vase and come in contact with the liquid. Imagine what you choose in the air—electricity, magnetism, ozone, unknown forces even, all can reach the infusion. Only one thing cannot enter easily, and that is dust suspended in air. And the proof of this is that if I shake the vessel violently two or three times, in a few days it contains animalculae or mouldiness. Why? because air has come in violently enough to carry dust with it.

"And therefore, gentlemen, I could point to that liquid and say to you, I have taken my drop of water from the immensity of creation, and I have taken it full of the elements appropriated to the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb, dumb since these experiments were begun several years ago; it is dumb because I have kept it from the only thing man cannot produce, from the germs that float in the air, from life, for life is a germ and germ is life. Never will the doctrine of spontaneous generation recover from the mortal blow of this single experiment." *

QUESTIONS AND EXERCISES

1. What specific problem did Francesco Redi hope to solve by his experiment with the rotten meat? What logical method did he use in this experiment? What conclusion did the experiment warrant?
2. What hypothesis was accepted by Needham and Buffon to account for the origin of various forms of life? What experiment did Needham perform in order to verify this hypothesis? What logical method did he use?
3. What error from the logical point of view is implied in Spallanzani's criticism of Needham's argument? How was this error overcome in the experiment which Spallanzani performed?
4. What objection did Needham offer to Spallanzani's argument? How was this objection met?
5. Just what conclusion could be drawn from Spallanzani's experiment? Why was it necessary to carry on further investigation concerning spontaneous generation?
6. The hypothesis which Pasteur wished to test was one that had to do with the development of microscopic organisms. He wished to know whether these organisms could be developed from the dusts which fly freely through the air. What were some of the factors in his experience that led to the formation of this hypothesis?
7. How did he verify the hypothesis that ordinary atmosphere is laden with dust? What logical method did he use?
8. How did he prove that dust particles which are found in the air are capable of producing animalculae? What logical method did he use?
9. Why was Pasteur's work sufficient to settle once and for all the question of spontaneous generation?
10. Give a brief account of the scientific imagination, deduction, and inductive methods respectively as they were employed in Pasteur's work.

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II

THE DISCOVERY OF THE CAUSE OF YELLOW FEVER

[From *Disease Prevention,* by H. Waite, pp. 47-50. By permission Thomas Y. Crowell Company]

As in other diseases in which the cause was not known, yellow fever was thought to be carried from person to person through direct or indirect contact or by fomites. Fomites are any object upon which infectious material may be deposited, such as clothing, eating utensils and various other objects. Bacteria were isolated from yellow fever patients and from the bodies of those who had died from the disease. None of the bacteria isolated stood the test of time and the means of transmission was not discovered until the autumn of 1900. Dr. George M. Sternberg, later Surgeon General of the United States Army, while stationed at Governor's Island in 1870, had his first experiences with yellow fever.

As early as 1848 the theory that yellow fever was transmitted by mosquitoes was advanced by Josiah Clark Knott of South Carolina. In 1881, Carlos Juan Finlay, of Cuba, expressed the same belief and in addition picked out the common mosquito in Cuba, then known as the *culex fasciata,* as the carrier of the infection. Not only was it later shown that the mosquito was the carrier but that the particular mosquito selected by Finlay, now known as the *aedes calopus* or *aedes argentus,* was shown to be the specific host. Surgeon General Sternberg was interested in Finlay's theory, but it was probable that he did not regard it with much seriousness. Finlay based his theory on two major premises, the correspondence of yellow fever zones with the distribution of this mosquito and the presence of these mosquitoes in epidemic areas.

In 1900 Surgeon General Sternberg appointed a commission to study sanitary conditions in Cuba. The Spanish-American War had just ended and sanitary conditions in Cuba were very bad. Malaria was prevalent and the dangers of yellow fever in the troops was very great. The commission was placed under the head of Major Walter Reed, Surgeon U. S. Army. Associated with him were Drs. James Carroll, Aristedes Agramonte, and Jesse W. Lazear. In August 1900, the commission began its work. Reed had been impressed with the belief of Finlay and eagerly set out to determine its value. The *aedes calopus* was the species to which attention was especially directed though others were included in the experiments. The mosquitoes were allowed to suck the blood from yellow fever patients and were later placed on susceptible individuals. They were allowed to remain there until they had bitten them several times. Of the first ten experiments only one was successful.

The reason why the first nine were negative was later determined and was found to be due to the fact that nothing was known of the life cycle of the parasite in the mosquito at this time. Later it was shown that the mosquito may obtain the blood from the patient during the first four or five days of the disease and that at least twelve days must elapse before it is capable of producing infection in man.

A member of the commission, Carroll, was the first of the volunteers to succumb to infection. He became ill four days after having allowed an infected mosquito to bite him. He recovered from the infection but died on March 9, 1907, of myocarditis which had undoubtedly been brought on through the previous attack of yellow fever. On the 13th of September, Lazear, while working in the wards occupied by yellow fever patients, noticed a mosquito on his hand. He did not remove it and as a result became infected, the symptoms of the disease appearing five days later. After a very serious illness, he died on September 25th, 1900.

A systematic campaign was now started. "Camp Lazear" was established in the country, a short distance from Havana, about a mile from Quemados. Three immunes and nine non-immunes, volunteers from the army of occupation, were selected as subjects of investigation. A strict quarantine was maintained, only the non-immunes and the members of the commission being allowed to enter or leave the camp. Non-immune volunteers who left the camp were not allowed to come back again, their places being taken by other non-immune volunteers. During December, January, and February, ten non-immunes became infected with yellow fever through mosquitoes.

Too much honor cannot be accorded to these enlisted men of the United States Army, who after calm deliberation, and in the absence of excitement and stress of battle, subjected themselves to an infectious disease which is so disastrous and fatal.

Experiments were now devised to show that yellow fever was transmitted by the mosquito alone, all other reasonable opportunities for being infected, being excluded. A small building was erected, all windows and doors and every other possible opening being absolutely mosquito-proof. A wire mosquito screen divided the room into two spaces. In one of these spaces fifteen mosquitoes, which had fed on yellow fever patients, were liberated, one of them 24 hours, 7 four days, and 3 twelve days after the feeding. A non-immune volunteer entered the room with the mosquitoes and remained there for nearly half an hour during which time he was bitten by seven mosquitoes. Twice after this he entered, remaining in it 64 minutes, receiving sixteen mosquito bites. Four days later, he suffered an attack of yellow fever. Two other non-immune men slept in the mosquito free room without disturbance of any sort.

To show that the disease was transmitted by the mosquito and not through the excreta of yellow fever patients or anything which had come in contact with them, another house was constructed and made mosquito-proof. For 20 days, this house was occupied by three non-immunes, after the clothing, bedding and eating utensils and other vessels soiled with the discharge, blood and vomitus of yellow fever patients had been placed in it. The bed clothing which they used had been brought from the beds of the patients who had died of yellow fever, without being subjected to washing or any other treatment to remove anything which had been soiled. The experiment was twice repeated by other non-immune volunteers. During the entire period all the men who occupied the house were strictly quarantined and protected from mosquitoes. That they were not immune was subsequently shown, since four of them became infected by mosquito bites or the injection of blood from yellow fever patients.

The following facts were demonstrated by the commission : Yellow fever is only acquired through the bite of the *aedus calopus.* The mosquito to become infectious must bite the yellow fever patient during the first five days of the illness ; some have since maintained that an interval of at least twelve days must elapse, after the mosquito has obtained blood, before it can infect man.

The importance of the results which have accrued from these discoveries cannot be overestimated. Yellow fever has been eliminated from the United States and practically so from the West Indies, and it is only a question of time when it will be eliminated from all parts of the world where it now exists.

QUESTIONS AND EXERCISES

1. Prior to 1900 it was believed that yellow fever could be transmitted by direct contact, or by fomites. What method of reasoning led to this conclusion ? Why was the conclusion weak ?
2. It is stated that Finlay's hypothesis concerning the *aedes calopus* was based on two major premises. What facts were included

in each of these premises? What logical methods could be used for the interpretation of these facts? Explain fully the way in which each one of the methods mentioned would be employed.

3. How did the members of the commission appointed by Surgeon General Sternberg proceed to test the value of Finlay's hypothesis?
4. Of the first ten experiments performed only one was successful. Why did not the negative results obtained from the other nine experiments prove that yellow fever could not be transmitted by mosquitoes? Just what did these ten experiments prove?
5. What was the significance for the problem under investigation by the commission, of the infections of Drs. Carroll and Lazear?
6. Describe the conditions of the experiment performed at Camp Lazear. What logical method is illustrated in the procedure of this experiment?
7. How was it proved that yellow fever cannot be transmitted by direct contact or by fomites? What logical method was used?
8. How was it proved that those who used the bedding and cooking utensils that had previously been used by yellow fever patients and yet did not become infected were non-immunes?
9. Show how the conclusions reached by this commission have been completely verified.
10. Explain in brief the way in which deductive reasoning was involved in the work of the commission.

III

EXPERIMENTS IN THE PSYCHOLOGY OF LEARNING

[From *The Fundamentals of Psychology*, by W. B. Pillsbury, pp. 368-378. By permission of The Macmillan Company, publishers.]

Careful experiments on memory were first made by Ebbinghaus in the eighties of the last century. To avoid the variation in degrees of familiarity and interest that might attach to words or any other material that has meaning, nonsense syllables were selected as the material to be learned. These were built up of consonants and vowels, two consonants with a vowel between. All combinations were excluded that chanced to make sense. Series were selected by lot from the mass of syllables.

Two methods have been used to test the accuracy of the learning or the amount of retention. The first, known as the method of relearning, was used by Ebbinghaus. It consisted in relearning the syllables, and assumed that the difference between the time required for learning and for relearning was a measure of the amount retained. This also measured the value of the method of learning used. In a second method, the method of paired associates developed by Müller and Schumann and extensively used since, the syllables are learned in pairs and the amount retained is measured by showing the first member of each pair and asking the observer to supply the second. The percentage of correct answers indicates the amount retained.

Each of these methods has given valuable results. They frequently supplement each other. The first measures primarily the effective and latent memory of the whole ; while the second permits a study of the effective connections between members of the pairs.

One of the first preliminaries to the application of the method was to determine the accuracy of the method itself. This involved first a determination of the effects produced by each repetition when a number of repetitions of the same series are made. Ebbinghaus tested this by repeating a series of syllables eight times and then finding the time required to relearn after twenty-four hours. He then repeated another series sixteen times and again relearned after the same interval. These experiments were repeated up to sixty-four repetitions of a series. Within these limits the amount retained after twenty-four hours was directly proportional to the number of original repetitions. The last repetitions were no less effective than the first as measured by the amount retained. Each repetition resulted in a saving of about twelve seconds in the time required for relearning. This experiment also brings out the fact that learning is never absolutely complete or perfect. Perfect learning at the moment will show defects in a few hours or days, and the duration and accuracy of retention may be increased by repetitions much beyond the number required for the first repetition.

One of the more striking facts in connection with learning is the great increase in the number of repetitions required for the longer series as compared with the shorter. It is found that an adult can remember from 6 to 8 syllables or 11 to 13 numbers with a single repetition, while Ebbinghaus found that it took 13 repetitions to learn a series of 10 syllables, 16.6 for 12, 30 for 16, 44 for 25, 55 for 36. As the number of syllables in a series increases, the number of repetitions required for learning it increases much more rapidly than in proportion to the increase in the number of syllables.

Learning a series not only forms associations between the contiguous syllables of the series, but knits the whole group together by associations formed between all the syllables, however widely they may be separated. Ebbinghaus demonstrated this by learning certain series and then making up new series that should consist in part of the syllables that had been separated by one syllable ; and he found that the new series could be learned more easily than new syllables. He repeated the experiment, using syllables that had been separated by two, three, etc., syllables, up to those that had been separated in the original learning by as many as eight. He found that in each case a saving could be shown as compared with entirely new series.

One of the most important practical laws for learning is that it is much easier to learn any selection if it is read as a whole instead of being learned by parts. This applies to nonsense material under strict experimental conditions, and also to ordinary sense material, poems, etc. An investigation of this point was first undertaken by Miss Steffens under the direction of Professor Müller. It consisted in comparing the time required for poems when learned as most people incline to learn them, a line or a couplet at a time, with the time required when they are read through from beginning to end each time. The results indicate that, in practically every case, learning as a whole is more economical than learning in parts. The saving amounted to about ten per cent. in Miss Steffens' experiments and held for children as well as for adults. Later investigations by Meumann showed that two stanzas required thirty-three repetitions by the part method, and only fourteen for the whole procedure.

Another law that is equally well established, quite as important in practice, and even more interesting, is the so-called law of divided repetitions. Briefly, this is that the more the repetitions are distributed over different days, the fewer the repetitions required and the more thoroughly the material is mastered. This conclusion was first carefully investigated by Jost. He tried learning nonsense syllables with twenty-four repetitions at one time, then similar series with eight repetitions per day for three days, then four for six days, and finally two a day for twelve days. It was found that when they were tested by the method of paired associates twenty-four hours after the last repetition, that the fewer the repetitions each day, the greater was the amount retained. Ebbinghaus had earlier compared greater numbers of repetitions. On one occasion he read a series of twelve syllables 68 times and found that twenty-four hours later he needed seven repetitions to relearn.

The explanation of the advantage of divided repetitions was suggested by some of the experiments of Jost. He found that, when he compared the number of repetitions required to develop completely two sets of associated syllables of equal strength but of different ages, the older set required fewer repetitions than the newer. His method was to learn one series of syllables twenty-four hours before and then to make a few repetitions of another series a few hours before the test. The amount retained was tested by the method of paired associates. When three times as many correct associates could be given from the newer series it required almost the same number of repetitions to bring each to the point where it could be said through without mistake. When the number of correct associates that could be given was approximately the same for both series, the older series could be fully learned much more easily than the more recent. His theory is that the associations continue to grow strong, to "set," for some time, perhaps for two or three days after they are first formed. That associations tend to increase in strength for a few days is known as "Jost's Law."

QUESTIONS AND EXERCISES

1. Nonsense syllables were used in the memory experiments instead of words which have meaning. What was the reason for using them?
2. Describe the method of relearning as a test for the amount retained. What logical method is illustrated by this process? Does this method yield a strong conclusion?
3. Describe the method of paired associates? What logical method does it illustrate? Does this method have any advantage over the method of relearning? Explain.
4. If ten repetitions of a series of nonsense syllables are necessary in order to commit the series to memory, how would you determine the value of the fourth repetition? What logical method would you use?
5. How would you determine whether the last repetitions are worth more than the first ones? What conclusion did Ebbinghaus reach with regard to this problem?
6. Show how the method of concomitant variations was used to determine the relationship between the number of repetitions and the amount retained.
7. What general principle may be used to express the relative number of repetitions required to learn a long series as com-

pared with the number required for learning a short series? What logical method was used to determine this?

8. How did Ebbinghaus determine that associations are formed between the remote, as well as the contiguous elements in a series? What logical method did he use? How would you criticize his argument?
9. What experiment did Miss Steffens use to determine the value of the "whole method" in comparison with the value of the "part method"? What conclusion did she reach? What logical method did she use? In view of the facts brought to light by her experiments how do you account for the general use of the part method in preference to the whole method?
10. What is Jost's "law of divided repetitions"? Describe the logical process which he used for the establishment of this psychological law.
11. What hypothesis was suggested by Jost to explain the greater value of divided repetitions? Criticize this hypothesis from the logical point of view.
12. What practical deductions could be made from this law of divided repetitions?
13. Mention at least three more problems that have to do with the learning process and describe the logical procedure which you would follow for dealing with each one of them.

CHAPTER XVIII

EXAMPLES OF REASONING IN THE PHYSICAL SCIENCES

I

EXPERIMENTS CONCERNING THE NATURE OF HEAT

[From *Theory of Heat,* by Thomas Preston, pp. 39-45. By permission of The Macmillan Company, publishers]

In the year 1798 a remarkable series of scientific investigations concerning the true nature of heat was begun by a man named Benjamin Thompson, better known as Count Rumford. Prior to this date the generally accepted idea concerning the nature of heat was expressed in the doctrine held by the calorists. According to their view heat must be regarded as a certain kind of substance. The name which they gave to it was *caloric.* This substance, they believed, was a kind of fluid made up of tiny corpuscles which mutually repel one another and which are capable of being drawn into a physical object through attraction and of being expelled from the same body by means of an opposite process. Thus the "hotness" of physical bodies was explained as being due to the presence of these heat corpuscles or caloric ; and "coldness" was explained as the result of this substance being driven out of the object in question.

This explanation would account for the fact that physical bodies, as a general rule, expand when they become hot and contract when they become colder. So long as heat is conceived as a thing or substance it follows that whenever heat is drawn into a physical body the volume of that body is thereby increased. And for the same reason it would follow that when a body becomes colder its volume is decreased. The fact that water expands when it is turned into ice and that the heat of a gas is increased when its volume is diminished could not be explained by this theory, but this difficulty was overcome, at least in part, by reference to the concept of latent heat.

Count Rumford was one of the first to challenge seriously the calorists theory of heat. While engaged in the process of boring cannon at a military arsenal in Munich he observed the high temperature of the metallic chips thrown off and also the excessive development of heat during the process. In order to investigate the matter thoroughly he prepared a hollow gun-metal cylinder, formed in the waste head of a cannon, and mounted it so that it could be rotated by horsepower on a horizontal axis, while a blunt steel borer was pressed against its base. The cylinder was covered with a thick coating of flannel, to prevent loss of heat, and a small radial hole was drilled into the base and terminated at its centre. The bulb of the thermometer was thus at the middle point of the thick base of the cylinder, and the stem projected from its side.

At the beginning of the experiment the thermometer stood at 60 degrees Fahrenheit, and after half an hour, when the cylinder had made 960 revolutions, the temperature was found to be 130 degrees Fahrenheit, which fairly represented the mean temperature of the cylinder.

After removing the metallic dust or scaly matter abraded by the friction from the base of the cylinder, Rumford found that it weighed only 837 grains troy. It seemed to him utterly incredible that so great a quantity of heat could have been extracted from so small a quantity of metallic dust, and this merely in consequence of a change in its capacity for heat. He knew from other experiments, which had been performed solely for the purpose of determining the fact, that the capacity for heat of the metal of which great guns are cast is not sensibly changed by being reduced to the form of metallic chips in the operation of boring cannon and he could see no reasons why it should be changed very much when reduced to smaller pieces by the use of a borer that was less sharp.

The one feature of the experiment upon which Rumford based his conclusion was the fact that the supply of heat was, so far as he could determine, inexhaustible. According to the position held by the calorists, the heat produced in the experiment must have been rubbed out of the metal. But if this were true, it would have been possible to reach a certain stage at which all the heat would have been exhausted. No such stage was ever observed. The supply was as free and copious at the end of the experiment as at the beginning. All that was necessary was the continued working of the machinery. The quantity of heat obtained depended in no way on the amount of rubbing or hammering the brass had previously received; it depended only on the work spent in friction during the experiment.

Rumford concluded the report of his investigations with the following words: "It is hardly necessary to add that anything which an insulated body or system of bodies can continue to furnish without limitation cannot possibly be a material substance ; and it appears to me extremely difficult, if not quite impossible to form any distinct idea of anything capable of being excited and communicated in the manner the heat was excited and communicated except it be MOTION."

Following the work of Count Rumford, another contribution toward the new conception of heat was made by Sir Humphry Davy. He showed that two pieces of ice may be melted by simply rubbing them together. For his experiment, he used two pieces of ice of the temperature 29 degrees Fahrenheit. These pieces of ice were each six inches long, two inches wide and two-thirds of an inch thick. They were fastened by wires to two bars of iron. By a peculiar mechanism their surfaces were placed in contact, and kept in a continued and violent friction for some minutes. They were almost entirely converted into water. This water was collected and its temperature proved to be 35 degrees Fahrenheit after it had remained in an atmosphere of a lower temperature for several minutes. The fusion took place only at the plane of contact of the two pieces of ice, and no bodies were in friction but ice.

From this experiment it was evident that ice could, by means of friction, be converted into water. According to the assumption of the calorists, its capacity for heat had thereby been diminished. But Davy knew from former experiments that the capacity of water for heat is much greater than that of ice. In fact ice must have an absolute quantity of heat added to it before it can be converted into water. Hence it could not be true that friction diminishes the capacities of bodies for heat.

Davy now proceeded to determine whether the heat which produced this liquefaction could have been derived from the air or bodies in contact with the ice. For this purpose he caused the experiment to be performed by clock-work under the exhausted receiver of an airpump surrounded by ice ; but in this case also liquefaction was produced as before. Consequently, he concluded that heat is produced by friction and that caloric or the matter of heat, does not exist.

These experiments were not however sufficient to cause the calorists to abandon their theory. It is true that in the experiments of both Rumford and Davy there is clear evidence that the heat in question has not been rubbed or squeezed out of the material. But the calorists could account for the inexhaustible supply of heat on the theory that the quantity of heat which was driven out of the body had been replaced by an equal amount which had been taken into it. Thus in Rumford's experiment it would have been possible to assert that the heat involved had come from the horse and this in turn had come from the food which the horse consumed. It was not until scientists were able to state accurately the quantitative relations between energy expended and units of heat produced that the hypothesis of a heat substance or caloric was definitely rejected. Even then at least one element of the calorists theory, viz., that heat can be neither created nor destroyed, was preserved, for it was later incorporated in the doctrine of the conservation of energy.

One of the first men to attempt an exact mathematical statement concerning the relation of energy and heat was Dr. James P. Joule of Manchester, England. The object of his inquiry was to determine exactly the quantity of heat developed by the expenditure of a known amount of work when this work is spent solely in producing heat by friction. The modification consisted in the adoption of accurate methods for estimating the work spent and the heat generated. The heat was produced by the friction of a brass paddle revolving in water contained in a specially constructed brass vessel, so that the water was heated by a kind of revolving-churn process, and the temperature was registered by means of a delicate mercurial thermometer. The paddle was driven by two leaden weights attached to a double cord over two pulleys, and the work spent in turning was estimated from a knowledge of the mass of the weights and the height through which they descended.

After all corrections were made, Joule decided that his mean result was 772 foot-pounds per degree Fahrenheit between the temperatures 55 degrees and 60 degrees Fahrenheit. That is, the work done in raising a weight of one pound through 772 feet in the latitude of Manchester will, if spent in friction between brass and water, raise the temperature of one pound of water one degree Fahrenheit on the mercury thermometer. The unit of work being that spent in elevating unit mass one foot, the general relation between heat and work will be $H = \frac{W}{772}$ or $W = 772\ H$.

If the unit of heat be that required to raise unit mass of water one degree Centigrade, the work equivalent will be nine-fifths of 772 or 1390, the unit of work being the same as before. But if the unit of work be that spent in raising unit mass one metre, the value of the mechanical equivalent of heat is 424 gramme-metres or the work spent in raising a weight of one gramme to a height of 424 metres will, if spent in friction, produce as much heat as will raise the temperature of one gramme of water one degree Centigrade. Denoting the value of the mechanical equivalent by J in any system of units, we shall have between the work spent and the heat produced the general equation $W = JH$. The symbol J represents the number of units of work necessary to the generation of one unit of heat, when the work is all spent in producing heat. Joule was quite clear on the point that if the work is really all spent in producing heat, then with every form of apparatus, we must obtain the same amount of heat for the expenditure of the same amount of work. He consequently determined the dynamical equivalent by the friction of other liquids than water, and by other methods of friction.

QUESTIONS AND EXERCISES

1. Explain the calorist's theory of heat. What factors do you think led to the development of this hypothesis? What facts could be explained by this theory?
2. What hypothesis did Rumford wish to test in his experiment with the horse and iron cannon-head?
3. Show how each of the following was illustrated in the case of Count Rumford's investigation: (1) the scientific imagination, (2) deductive reasoning, (3) the use of inductive reasoning.
4. What inductive method was used in the interpretation of Rumford's experiment? Explain.
5. Why did he attach so much significance to the fact that the supply of heat was inexhaustible?
6. Did Rumford's experiment disprove the theory held by the calorists? If not, how could they explain the results which he obtained?
7. How could Rumford have determined whether the capacity for heat of the metallic chips was as great as that of the solid metal? What logical method would he have used?
8. Could the method of residues be used to interpret the results of Rumford's experiment? Explain.
9. It has been said that Sir Humphry Davy's experiment with the two pieces of ice struck a fatal blow to the calorist's theory. How would you criticize this statement?

10. What logical method did Davy use to determine whether the surrounding air had any effect on the liquefaction of the ice?
11. Could the method of agreement be used to interpret the experiments of both Rumford and Davy? If so, how would you criticize the conclusion?
12. What problem did Joule hope to solve by means of his experiment? Discuss the function of hypothesis and deduction in connection with this experiment.
13. What logical method is illustrated in his experiment and the interpretation which he placed upon it?
14. Discuss the significance of Joule's work in connection with the development of the modern theory of heat.

II

The Michelson-Morley Experiment

[A brief description of this experiment may be found in W. C. D. Dampier-Whetham, *A History of Science*, pp. 417-419]

One of the chief points of contrast between Newtonian physics and the interpretation which belongs to the theory of relativity has to do with the conceptions of space and time. The doctrines of Newton in so far as they set forth his conception of the nature of the physical world were based upon the assumption of an absolute space and an absolute time. He distinguished between a relative space and time which is measured by our human senses in terms of natural bodies in motion and an "absolute space which exists immovably" and an "absolute time which flows equably without regard to anything external." According to modern relativists, the conceptions of space and time are so interwoven and mutually interdependent that neither one can have any meaning apart from the other. All of our notions of space are based on units of time, and likewise our notions of time are built upon units of space. It is meaningful to speak of space-time, but we cannot admit of an absolute space or an absolute time.

The Newtonian conception, as we all know, was the generally accepted one until recent times, and it was not until a considerable amount of experimental evidence had indicated the inadequacy of Newton's theories that the newer views came to be accepted. One of the most interesting and significant experiments in connection with the development of the new physics is known as the Michelson-Morley experiment. Professor Albert A. Michelson, of the University of Chicago, was one of the most distinguished of American physicists. He was assisted in this experiment, which was performed in 1887, by Mr. Edward W. Morley. Later repetitions of the experiment have tended to verify the conclusion which was reached.

Newtonian physicists with their notions of absolute space and time had found it necessary to postulate the existence of an ether-substance which permeated and filled all space. It seemed impossible to think of a distant object as having any effect upon us except as the action would take place through some physical medium. How could light from a distant star ever reach our earth unless there was some substance upon which it could act and which in turn could transmit the action to us? The existence of this hypothetical ether, if it could be demonstrated that it really existed, would enable us to think of light as traveling in a straight line with an absolute motion through space. It was for the purpose of demonstrating the existence of this ether-substance and of detecting the motion of the earth through it that the Michelson-Morley experiment was performed. If the earth, traveling through its regular orbit at the rate of more than eighteen miles per second, passes through a stationary ether it would in so doing create a kind of wind or ether drift. The situation would be analogous to that which happens when a motor car is driven at high speed through air that is not in motion. Using the known speed of light as a constant factor, the experimenters believed that by sending a ray of light equal distances both in the direction of the earth's movement through the ether and at right angles to this direction they would be able to detect the ether drift and thus prove experimentally that ether is a stationary medium through which it is possible for motion to take place.

For the purposes of their experiment they used a mechanical device built of steel and weighing several hundred pounds. In order to prevent vibration the apparatus was mounted on stone and placed in a trough filled with mercury. It contained two arms each about fourteen feet in length and placed at right angles to each other. At the point where the two arms intersected there was placed a mirror half of which was silvered and so arranged that when a beam of light would strike it, half of the beam would be thrown toward the extremity of one of the arms and the other half toward the extremity of the other one. At the opposite ends of these two arms which were at right angles to each other there was placed a series of parallel mirrors.

The apparatus thus constructed made it possible to break a beam of light into two parts and have each part reflected back and forth equal distances on these respective arms. The only significant difference, so far as the reflection of light on the two arms was concerned, was that the reflection in one case would be in the direction of the supposed ether drift while in the other case it would be at right angles to it. Since the mirrors placed at the ends of the two arms were set at right angles, the two beams of light after traveling their respective courses would be reflected back upon their own paths and finally reach the observer's telescope where both sets of images could be examined.

The experimenters expected that the influence of the ether could be recognized by a difference of interference fringes between the two sets of images. In accordance with the wave theory of light it is possible for two light waves to come together so that the crest of one wave will be exactly opposite the trough of the other, or one crest can be exactly opposite another crest. In the first case the effect will be that of complete neutralization or darkness, while in the second case the amount of illumination will be increased. If the wave crests of one do not coincide exactly with either the crest or the trough of the other, there will be a lessened amount of ether interference or reinforcement. Now in the case of the experiment the light waves traveling back and forth on each of the two arms, would be reflected back so as to produce a definite set of light and dark bands or in other words interference fringes. Any difference in the speed of light on the two arms would be noticed by a difference in the relation of these interference fringes with each other.

Since they were confident that the movement of the earth through the ether would produce a difference in the speed of light along the two arms and that this difference would become manifest in the shifting of the light and dark bands, the experimenters hoped in this way to prove experimentally and beyond any question the existence of the ether. Not knowing the direction of the earth's movement through the ether the experiment was performed several times with the apparatus moved to different positions. It was also performed at different times of the day and at different seasons of the year.

The surprising thing about the experiment was that no more than a slight trace of a shifting of the interference bands could be detected. Certainly the variation was much less than had been expected. In fact the results obtained by the experiment indicated practically no difference in time for the two rays of light.

One of the interesting explanations given for the negative results of the Michelson-Morley experiment is known as the Fitzgerald-Lorentz contraction. These two physicists (Fitzgerald from Dublin, and Lorentz from the University of Leyden) maintained that all bodies which pass through the ether undergo a contraction in the direction of the movement. Hence the difference which was expected with reference to the course of the two beams of light could be exactly accounted for by a shrinking of the instrument used for measurement.

QUESTIONS AND EXERCISES

1. Explain briefly the Newtonian conception of absolute space, showing how it differs from the one held by the modern relativists.
2. Why did the Newtonian physicists find it necessary to postulate the existence of an all-pervading ether? Analyze, from the point of view of logic, the argument upon which this hypothesis was based.
3. How did the scientists who conducted this experiment hope to obtain experimental verification of the hypothesis?
4. Discuss at some length the function of the scientific imagination and also the use of deductive reasoning prior to the actual performance of the experiment.
5. Describe in brief the kind of apparatus used in the experiment.
6. What was the logical reason for having the apparatus floated in a trough of mercury?
7. What was the basis for their anticipation of different results from the two rays or beams of light?
8. What is meant by "interference fringes"? Why was it necessary for the experiment to be performed with the apparatus in different positions and at various times of the year? What logical method is illustrated here?
9. What was the unexpected result of the experiment?
10. Explain briefly the Fitzgerald-Lorentz contraction and tell how it was applied to the results of the Michelson-Morley experiment.

CHAPTER XIX

ILLUSTRATIONS OF LOGIC FROM THE SOCIAL SCIENCES

I

ARE CRIMINAL TRAITS INHERITED?

[From *Criminology*, by E. H. Sutherland, pp. 112-116. By permission of J. B. Lippincott Company, publishers]

A LARGE part of the discussion concerning the causes of crime has centered around the discussion of the respective influences of heredity and environment. Many attempts have been made to prove the inheritance of criminal traits and the same may be said concerning the opposite position. As a general rule biologists are inclined to stress the importance of heredity, and sociologists are more likely to stress the importance of environment. From a logical point of view the problem is a difficult one. Nevertheless, it is an important one since the treatment that is appropriate for hereditary qualities is obviously very different from that which should be administered in the case of defective qualities due to the environment.

One of the most common arguments in support of the theory that criminal traits are inherited is based on a study of family trees. It is frequently pointed out, for instance, that out of 1200 descendants of the Jukes family 140 criminals were found, of whom 7 were convicted of murder, 60 of theft, and 50 of prostitution. Again the Kallikak family had among its members 3 who were convicted of felonies, 24 of confirmed alcoholism, and 33 of sexual immorality (mostly prostitution) out of 480 descendants from an illegitimate mating of a Revolutionary soldier and a feeble-minded woman, while there were no known criminals among the offspring of the same soldier and a normal wife. In the Zero family, with about 800 descendants in six generations, 7 were convicted of murder, 181 of prostitution, and 76 of other serious offenses.

From these facts it is evident that a high percentage of criminality is frequently found in successive generations. Criminal ancestry is seen to be a common factor present in each of the three families mentioned, and for this reason it is said to be causally related to the phenomenon in question. This conclusion seems to find further support in the facts presented concerning the two branches of the Kallikak family. The feeble-minded woman was a common ancestor in the case of the one family but a normal woman was the corresponding ancestor in the case of the other family. Since defective ancestry was present in the one case but absent in the other the conclusion would seem to follow that this factor was the cause of the high percentage of criminality. But neither of these arguments is logically valid. The appearance of a trait in successive generations does not prove that it is inherited. There is the same logic in asserting that eating with a fork is inherited because it appears in successive generations as in asserting that criminality is inherited because it appears in successive generations.

Others have tried to show not only that criminality appears in successive generations, but also that it appears in accordance with the Mendelian ratios and must therefore be inherited. The investigations of Goring, Estabrook, and others have shown no close approximation to the Mendelian ratios, but Carl Rath, in a study of family histories of 98 inmates of a penal institution at Siegburg, Germany, found, according to his report, that the offspring were criminal in a ratio which is fairly close to the Mendelian ratio. Aside from the fact that the number of cases studied by Rath is small, there is the further difficulty that since criminalism is assumed to be a recessive trait, the only way that the trait of an ancestor who does not have a criminal record can be determined is by assumption from the criminal record of the offspring. This is a necessary difficulty in dealing with human beings whose breeding and life conditions cannot be controlled for a sufficient length of time to determine whether a strain is "pure," as can be done in experiments with plants and the lower animals.

Goring attempted to prove by elaborate correlations that the criminal diathesis or criminalistic tendency is inherited and that environmental conditions are of slight importance. He found that criminality, measured by imprisonment of fathers and sons, was correlated by a coefficient of +60, which is very nearly the same as the coefficient for stature, span, length of forearm, eye color, diathesis of tuberculosis, insane diathesis, and hereditary deafness; and that brothers had a coefficient of correlation of +45, which is approximately the same as for physical traits. But Goring realized that such correlations might be the result either of heredity or environment or both, and he attempted to eliminate the factor of environment, on the hypothesis that if the influence of environmental factors is found to be low, heredity will, by elimination, be the explanation.

Therefore he divided environmental factors into contagion and force of circumstances, and his argument concerning them is as follows: (a) The resemblance of fathers and sons regarding criminality is not due to contagion; first, because the coefficient of correlation is no higher in crimes such as stealing, in which fathers would be examples for their sons, than for sex crimes which fathers would attempt ordinarily to conceal from their sons and in which therefore they would not be examples; second, because children taken away from the influence of their parents at an early age by imprisonment become confirmed criminals to a greater extent than those taken at a later age. (b) This resemblance is not due to the force of circumstances, such as poverty, standard of living, or ignorance, because, after the influence of defective intelligence is eliminated by the use of partial correlations, there is found to be an almost negligible correlation between criminality and these factors included under the head of force of circumstances.

These arguments and methods that Goring used are open to criticism at a great many points, but without multiplying criticisms, the following defects are found in his argument:

(a) His raw materials are in most cases the statements of the convicts, without verification and are thus untrustworthy for statistical purposes.

(b) He attempts to determine the importance of the residual element, heredity, by eliminating the factor of environment; in order to do this accurately, it would be necessary to measure completely the influence of the environment.

(c) He considers only eight environmental factors, and it is possible that the coefficient of correlation between criminality and each of these might be very low even though environment as a whole was extremely important.

(d) He restricts parental contagion entirely to the teaching of technique of a particular crime, such as stealing. As a matter of fact it is not so much the transmission of a definite technique of crime that is important as the transmission or contagion of a general attitude toward law and social authority. Again and again cases occur in which the sex delinquency of the parents tends to produce stealing in the offspring.

(e) The removal of the child from the home to prison at an early age does not remove the child from a criminalistic to a non-criminalistic environment as Goring assumes.

(f) He restricts his study to male convicts but mentions the fact that, measured by his standard, the ratio of sisters to brothers in respect to criminality is 6 to 102. If criminal diathesis is inherited to the same extent that physical traits, such as the color of the eyes, are inherited, it must affect females to the same extent as males, unless it is sex linked. But since, according to Goring, the diathesis consists entirely in physical and mental inferiority, there is little reason for believing that it is sex linked.

QUESTIONS AND EXERCISES

1. One of the arguments used to prove that criminal traits are inherited is based on a study of the two branches of the Kallikak family. What inductive method is used in this argument? How would you criticize the argument?
2. What inductive method would you use to interpret the facts obtained with reference to the three families, viz., Kallikak, Jukes, and Zero? Would the method used yield a weak or a strong conclusion? Give reasons for your answer.
3. Does the appearance of criminal traits in successive generatons prove that these traits are inherited? Explain.
4. What method of reasoning was used by Carl Rath in his attempt to prove that criminal traits are inherited? Point out the weaknesses in his argument.
5. Describe in brief the argument used by Goring to prove the inheritance of criminal traits. What logical methods did he employ?
6. To prove that criminal traits are inherited, Goring realized that it was logically necessary to exclude as a causal factor the influence of environmental factors. What was his procedure for doing this? Was his argument valid? Give reasons for your answer.
7. What inductive method did Goring use to prove that contagion is not a causal factor? Criticize this part of his argument.
8. In the absence of any high degree of correlation between criminal traits and any one of the eight environmental factors, Goring concludes that environment taken as a whole is not a causal factor. What deductive fallacy does this illustrate?
9. Why do the facts mentioned concerning the presence of criminal traits among females tend to disprove Goring's hypothesis?

10. Does the fact that more males than females are convicted of crime prove that criminal tendencies are present to a greater degree among men? Explain.
11. From the logical point of view what seems to you to constitute the best approach toward the solution of this problem?

II

THE USE OF INTELLIGENCE TESTS

[From *Applied Psychology*, by Bernard Ewer, pp. 96-107. By permission of The Macmillan Company, publishers]

Intelligence tests are a combination of various features found in scholastic examinations, intellectual and practical puzzles of different kinds, and certain forms of psychological experimentation performed with or without the aid of apparatus in the laboratory. Various devices possessing these features are put in the form of definite tasks and problems, and are applied experimentally to large numbers of individuals. The results are interpreted by means of the mathematical concepts used in the statistical researches of anthropology and sociology. The purpose is to formulate and apply standards of intelligence so as to determine with precision the efficiency of the individual or the general level of capacity in a group.

The contemporary development had its principal origin in the remarkable work of a French psychologist, Alfred Binet, who with a collaborator constructed the famous Binet-Simon system of intelligence tests. This psychological instrument was used to measure the mental age of French school children, and thereby to indicate not only how far the intelligence of a particular child diverged from the normal, but also whether such dullness as appeared in school work was due to inborn inability to learn or to less fundamental factors of disposition and environment. The system as formulated by Binet included a set of tests for every year of childhood from three to ten, and further sets for the ages of twelve and fifteen and for adults. There were five tests for each set except for the fourth year, which had only four. At the age of three, for example, a normal child is able to point to nose, eyes, and mouth; repeat two digits; enumerate objects in a picture; to give family name; and repeat a sentence of six syllables. At six he should distinguish between morning and afternoon, define similar words in terms of use, copy a diamond, count thirteen pennies, and distinguish pictures of ugly and pretty faces. The materials of the tests, such as pictures to be described, words to be defined, figures to be copied, questions to be comprehended, and so on, were selected methodically and with the greatest care. Precisely here, in fact, lay the scientific genius of Binet and the resulting value of the method. The tests were aimed at typical or fundamental operations of intelligence.

The problem of formulating a test has two distinguishable aspects, namely, the general character of the test and the particular norms or standards of success in performing it. With regard to the first point we should note that a mental test is a typical mental operation. It may be simple and elementary or highly complex; but in any case it is obtained by observation and analysis of conscious behavior. However odd or meaningless it may appear it always purports to exhibit some characteristic function of the mind. As a matter of fact the tests in ordinary use have been constructed by professional psychologists who were presumably most familiar with the workings of the mind. Such tests, first formulated in a tentative way, are applied to a large number of persons and on this basis are perfected in form.

The purpose of intelligence tests is not only the discovery of one's ability to perform successfully certain operations, but the formulation of definite norms or standards of intelligence. For example, they aim to develop a standard test of intelligence for children ten years of age. The development of these norms for general intelligence is made possible by examining large numbers of individuals and discovering to what extent they agree and differ in their performance. The results of such examination, when compiled according to statistical principles, show precisely the various degrees of efficiency which regularly characterize the operation of intelligence and, consequently, what may be expected of a majority in a large group.

Thus the nature of the mind, when scrutinized carefully, itself reveals what is normal. On the other hand, standards for particular purposes such as vocational selection depend more or less upon the arbitrary opinion of those who have given the most study to the subject. A consensus of experts decides with some approach to certainty what degrees of excellence are requisite for special purposes. In any case it should be noted that the proper formulation of a test implies that it agrees with some other actual or ideal standard which is assumed to be true. This standard may be nature's own average or majority, or it may be some form of authoritative opinion.

To put the matter concretely, entrance qualification tests for college are formulated by persons who have special acquaintance with the aims and methods of college work. Similarly the "good memory" needed by the salesman, or the accuracy of discrimination and quickness of reaction requisite for type-setting may be determined by those whose opinion decides what constitutes skill or success in these occupations. But apart from such special purposes, memory, discrimination and reaction time, as the student of psychology knows, are traits in which individuals not only differ, but differ in relation to so-called "averages." To ascertain such averages or other quantitative standards with statistical exactness is a large part of the task of mental measurement.

To determine the mental age of an individual Binet employed the following method. The correspondence of a test with a particular age was determined by placing it at the point where seventy-five per cent. of those tested performed it successfully and twenty-five per cent. failed. This was on the assumption that half the whole group may be regarded as normal, a quarter supernormal, and a quarter subnormal. Beyond the age of fourteen or fifteen it becomes practically impossible to equate particular tests to successive years of growth, since by this time the fundamental functions of intelligence have developed, and further advance consists of acquiring new kinds of information and new complex forms of operation which are so different in character and depend so much on the specific environment of the individual that representative tests can hardly be given.

Given a series of tests, or rather a set of tests for successive years, the mental age of an individual is ascertained by discovering how far along in the series he can successfully answer the questions or perform the work. In a typical subnormal case mentioned by Starch, for example, a boy approximately fifteen years of age was tested by the Terman Revision (a revision of the Binet-Simon tests). He passed all of the tests for three years, but failed in one of those for four, in two for five, in four for six, and in all for seven. Since he passed twelve tests beyond the age of three, twenty-four months or two years, was added to the latter, making five years his mental age.

The important question about an individual child, however, is usually not simply his mental age, but rather how this is related to his age in years. This relation, termed his intelligence quotient and commonly designated as his "I Q," is obtained by dividing the mental age by the chronological age. Thus if an eight year old child has a mental age of eight, his intelligence quotient is one or 100 per cent; if his mental age is ten, his I Q is ten-eighths or 125; if only six, his I Q is 75.

QUESTIONS AND EXERCISES

1. Describe the general nature of an intelligence test and show how the method of sampling is illustrated in the use of a particular test.
2. What logical procedure would you follow in order to determine whether a given test was a fair one?
3. Describe the logical procedure involved in the formulation of an intelligence test. Why are psychologists better prepared than others for doing this work?
4. Why is it more difficult to devise a reliable test for a fifteen year old than for one who is three years of age?
5. What is meant by "nature's own average or majority"? How can a psychologist determine whether his particular test conforms to nature's average?
6. How would a vocational test differ from a general intelligence test?
7. How would you determine whether a given vocational test was a reliable one? Describe the logical process involved.
8. What is meant by mental age? How did Binet determine mental ages with reference to the tests which he devised?
9. What is meant by the intelligence quotient? How is it obtained? How would you determine whether one's intelligence quotient remains constant throughout life?
10. How would you criticize the validity of intelligence tests as they are employed today? How would you test the validity of your own criticisms?

CHAPTER XX

REASONING IN THE FIELD OF HISTORY

I

LOGIC AND HISTORICAL METHOD

Reasoning in the field of history is distinct from reasoning in the physical and the biological sciences only because it is here employed in a different field of inquiry. The principles of correct thinking are essentially the same regardless of the field in which they may be used. It is for this reason, as we have noted before, that a person who is familiar with the requirements of logic in one field will be able to recognize sound thinking and to detect fallacies in any other field. Hence we can see that from one point of view there is nothing peculiar about the methods of thinking which characterize historical inquiry. The same logical principles are used in this field as in any other branch of knowledge. The unique thing about historical method is the particular purpose for which logical methods are used. In other words, it is the subject-matter of history that differentiates this field from all the other sciences. Historical method is nothing other than the use of sound methods of thinking for the purpose of solving those problems that are peculiar to this particular field.

A clear statement concerning the nature of history and the methods of reasoning employed in this field of science may be found in Professor F. M. Fling's book entitled *The Writing of History* (published by Yale University Press, New Haven, Conn., 1920). A brief summary of his argument will now be presented.

History, we are told, deals with the whole range of man's social activities. "It describes them, however, not in a state of repose, but of movement and of change. In this change our attention is drawn not to what repeats itself, but to what is new, what has never happened before and can never happen again. From all this it is evident that the historian is concerned with tracing the unique evolution of man in his activities as a social being." (pp. 15, 16).

A sharp contrast is drawn between the way in which social events are treated by the historian and by the sociologist. The latter is interested not in the unique elements that are present in social activities, but rather in those factors that are not unique. He studies his materials for the purpose of making generalizations, and of discovering the laws and principles which govern human activities. Because his quest is for the repeatable in social events he must employ the methods of the natural scientist. These methods are adequate for bringing to light the fixed and unchanging principles of human society. But the historian is interested in something else. He wants to construct a synthesis which will present a view of the whole and which will at the same time preserve the unique qualities which belong to each one of the events that he records. To do this he must employ a totally different type of procedure from that which is used by the natural scientist.

This contrast of methods is further illustrated by means of a figure. Suppose one is seated before a table on which there has been placed a large number of pieces of glass, of many shapes, sizes and colors. The problem is that of putting these pieces of glass together so that they will fit into a frame of a given size. There are two ways in which this may be done. The first one is to take the pieces of glass and melt them together. The resulting uniform mixture can then be poured into a mould of the size that is desired. The second method of solving the problem consists of taking the pieces of glass one at a time and fitting them in a kind of mosaic, which will constitute a synthesis of all the pieces without destroying the individual characteristics of any of them. The first of these two methods is analogous to the procedure of the natural scientist, while the second one resembles the work of the historian. Because the natural sciences deal with the uniform or with the repeatable in human experience they constitute a sound basis for making predictions. But the historian can never predict on the basis of his science. Neither can he use experimenation to verify the results which he has obtained from his studies.

The materials with which the historian works are known as his sources. These are "the remains of man's unique activities as a social being." They are divided into two groups technically known as "remains" and "tradition." The first group includes such objects as the remains of a human body, of buildings, pictures, instruments, customs, laws, etc. They may be viewed directly and inferences drawn concerning them. The second group includes impressions that have been made upon some human mind by past events, which were intended at the time of their origin to convey information concerning these events. The traditions may be oral, written or pictorial. "The first step taken by the historian in the attempt to reconstruct man's unique social past is to bring together all the sources that can be discovered containing any information on the period under investigation. Once collected, the sources must be subjected to a rigorous criticism to determine the value of the affirmations in each tradition and the relation of the affirmations to each other." (p. 25.)

The critical evaluation of source materials is one of the most important parts of historical method. In dealing with the materials included under the class of traditions, the historian regards that which is oral as the least reliable. Written tradition is considered the most reliable, and pictorial tradition occupies a place that is midway between the other two. The reason for this is that oral tradition is the least stable of the three kinds. Impressions that are preserved only by word of mouth are likely to be changed or at least modified each time they are repeated. In the case of the written record the impression has become permanent. It can now be passed on from one generation to another without change or modification. Knowing that the record is going to be permanent and that others may check up on its accuracy, the author will have reason to be more careful in the statements which he makes. In the case of the pictorial record, the element of permanency is also present. But pictures may serve other purposes than that of recording accurately events that have taken place. They may represent the idealizations of the artist or portray by means of symbolism some lesson which he wishes to teach. Hence their value as source material for the historian is, though greater than oral tradition, less than that of written tradition.

With reference to written traditions, Professor Fling says, "The whole problem of the evaluation of a source is one of the relations of the witness to the fact reported. It resolves itself into certain minor problems:

(1) Is the source genuine or is it a forgery?

(2) Who wrote it and when and where was it written?

(3) Do the affirmations contained in the source relate to the witness' own observation or are some of them hearsay?

(4) In the latter case, where was the information obtained?

(5) Finally, all these questions having been answered, what is the value of such a source?" (pp. 49, 50).

The question of the genuineness of a given document can be settled only by examining the contents to see whether or not the idea of the alleged authorship is in harmony with all the facts that are known concerning the whole problem. If facts are brought to light which are absolutely inconsistent with the claim that is made, then this claim must be regarded as false.

As an example, reference is made to *The Journal of a Spy in Paris during the Reign of Terror, January-July* 1794 by Raoul Hesdin. The idea that this document had been written under the conditions that were professed in the title was contradicted by statements found within the document itself. Events were recorded, according to this journal, before they ever happened. Many of the dates given in the text were shown to be inaccurate, some of them erring by as much as six months. In the light of these facts it was no longer possible to regard the document as anything other than a forgery.

The second question with which the historian is concerned in the evaluation of his sources has to do with the time and place of writing. "It should never be forgotten that the value of the affirmations in a source depends on the character of the source, on the personality of the witness and the time and place of writing." (pp. 61, 62). The character of an author, unless one can learn about it from some other source, must be determined by studying the contents of the document that he wrote. The type of person that he is has much to do with the reliability of his testimony. The question of his personal honesty, whether or not he was capable of telling the truth, and the presence or absence of any motive for writing what he did, all have an important bearing on the value of his testimony. The time when the author lived and the place where his observations were made are also important items for the historian to consider. If the event which he has described is one that happened long before he was born or in some other part of the world than the one in which he lived his testimony is not first-hand. It must be based on the testimony of others. The historian must then investigate the reliability of the sources that were used, and so on until he reaches the testimony of two or more independent eye-witnesses. The farther removed any testimony or document is from the original sources, the greater is the possibility of error being present in it. "The longer the interval of time, the more untrustworthy the record." (p. 69). Again it makes a difference whether the writer is depending wholly upon his memory or whether he is using records that were made at the time when the event occurred or soon afterwards.

Sometimes when the historian is reading and criticizing his sources he discovers that an event has been described in exactly the same way by two different writers. This does not establish the authenticity of the account but indicates that probably the two writers have used the same source and that they have copied the material instead of restating it in their own words. "The basis for the assumption is the psychological truth that no two independent witnesses can report the same detailed event, giving the same details, in the same order and in the same language." (p. 89). When these conditions are found the historian must recognize the nature of the problem and proceed towards its solution by a thorough examination of all the relevant facts which may be obtained.

Finally, the historian must criticize his sources with reference to the possibility of the thing recorded having happened. For this reason credence cannot be given to miracles or to any account which is contrary to well established principles of natural science. "It must be remembered that the foundation of the whole process of historical proof is possibility. If a thing is not possible, we cannot adduce sufficient historical proof to show that it was probable or certain." (p. 105). It is of course recognized that what is regarded at one time as an impossibility may at a later time be recognized as possible. For a man to fly through the air from one part of the country to another would have been an impossibility for the period of the Middle Ages but we know that it is not uncommon for it to happen today. The historian must then evaluate his sources in the light of the best scientific knowledge of his own day.

QUESTIONS AND EXERCISES

1. What is the subject-matter of history? How does the field of history differ from that of the natural sciences? What is the function of logic with reference to each one?
2. Does history ever repeat itself? Explain your answer. Why is it impossible for the historian to make predictions?
3. Discuss the way in which social events are treated by the sociologist and the historian respectively.
4. Why is it that experimentation is useful to the natural scientist but cannot be employed by the historian?
5. Show how the contrast between the methods of the historian and the natural scientist is illustrated by Dr. Fling's figure of the pieces of colored glass.
6. Distinguish between the so-called "remains" and "tradition" and tell how they are used by the historian. Why is written tradition considered more reliable than oral or pictorial tradition?

7. What logical method is employed to determine whether a given document is a forgery? Explain. Show how this logical method was employed in the case of *The Journal of a Spy in Paris during the Reign of Terror.*
8. Discuss from the logical point of view the significance of each of the following: (a) personality of the writer, (b) time and place of writing, (c) testimony of two or more independent eye-witnesses.
9. If two accounts of a given event are found to be in essential agreement, how would you determine whether one or both of them have been copied from some other source? What attitude does the historian take toward the subject of miracles? What is meant by "scientific possibility"? Is it the same for all periods of history?

II

AUTHORSHIP OF THE PENTATEUCH

It is generally known that there are two views concerning the authorship of the Pentateuch or the first five books in the Old Testament. According to the older of these two views, the books were all written by one man, Moses, who was inspired by God and who wrote in accordance with the revelation which he had received. According to the second view these books have a composite authorship. They are made up of four separate narratives, written by at least four different men who were separated from each other in point of time by one to four centuries. The name by which this view is generally known is the *Documentary Hypothesis.* In accordance with this position it is maintained that the oldest of the four narratives, the one known as J, was written by a prophet of the southern kingdom sometimes during the latter half of the ninth century B.C. The second narrative, designated by the letter E, was written about a century later by a prophet of the northern kingdom. The third narrative or D, which includes the major portion of our present book of Deuteronomy, was first published in the year 621 B.C. And, finally, the fourth narrative, the symbol for which is the letter P, was written about 450 B.C. by someone who was entirely sympathetic with the priestly conception of religion. After these separate documents had been in existence for some time they were woven together into a single continuous story with the result which we now have in the present arrangement of books in the Old Testament.

The question of which one of these two views is the correct one is a problem for historical criticism. To settle the issue one needs to study all the evidence contained within the books themselves and to select the hypothesis which is most completely in harmony with all the facts brought to light. If any claims of authorship are based on materials outside the Old Testament, it will be necessary to examine these claims as well.

In support of the older view which accepts the idea of the Mosaic authorship the following facts are relevant. (1) The books in question are called the Books of Moses in the titles given them in the Old Testament. (2) The first five books of the Old Testament have for centuries been regarded by the Hebrews as the "Book of the Law," and Moses has long been considered the great Law-Giver of the Hebrew people. (3) The Mosaic authorship of these books was accepted by the early Christian Church and for centuries was never questioned. (4) This view is in harmony with the conception of inspiration which was affirmed by the Council of Trent in 1584 and which for centuries was a universally accepted doctrine of the Christian Church. (5) Quotations from these books found in the New Testament are usually attributed to Moses.

A complete statement of the evidence in support of the idea of a composite authorship would require a considerable amount of space. Only a brief reference to some of the most important facts will be given here. One of the first men in modern times to question the Mosaic authorship of the Pentateuch was a Portuguese Jew named Baruch Spinoza. He called attention to the fact that in the third chapter of Deuteronomy and the eleventh verse mention is made of the giant iron bedstead used by Og the king of Bashan. The passage related that this bedstead was preserved as a relic in the city of Rabbath. According to another passage found in the twelfth chapter of Second Samuel, the city of Rabbath was first conquered by the Hebrews during the reign of David. Since David did not live until several centuries after Moses, it must be that the latter had never seen or heard of Rabbath. How then could he have written that story concerning the iron bedstead? Again the last chapter in the book of Deuteronomy contains an account of Moses' own death, and concludes with this statement, "No man knoweth of his sepulchre unto this day." It is conceivable, in accordance with the traditional view, that Moses might, during an inspired moment, have written beforehand concerning his death and burial. But would he have used the expression "until this day"?

Spinoza discovered too that in the twenty-first chapter of Genesis there is a story concerning the origin of the name of the city of Beersheba. It says that Abraham named the place and gives his reason for so doing. But in the twenty-sixth chapter of the same book another account is given of the naming of this place. This account says nothing about Abraham but declares that Isaac did the naming. How could one person have written these two contradictory accounts? Once more, Spinoza pointed out, in the twelfth chapter of Genesis and the sixth verse there is a statement which reads "And the Canaanite was then in the land." Now it is a well established fact that the Canaanites were not completely subdued by the Hebrews until the reign of Solomon several centuries after the death of Moses. The passage just quoted does not then make sense unless we suppose that it was written after the Canaanites had been driven from the land. Finally, Spinoza made mention of the fact that in the third verse of the twelfth chapter of Numbers this statement is found: "Now the man Moses was very meek, above all men that were upon the face of the earth." It is quite possible that this is a true statement concerning the character of Moses, but is it reasonable to suppose that the meekest man who ever lived would have written this statement concerning himself? If he did write it, how can it be said that he was really meek? Spinoza believed that this statement, at least, must have been written by some one other than Moses.

Shortly after the publication of the book in which Spinoza pointed out the above mentioned facts a French priest named Richard Simon began a careful study of the book of Genesis which threw more doubt upon the idea of Mosaic authorship. He called attention to the fact that the first two chapters of this book contain two separate and complete accounts of the story of creation. These two accounts may be distinguished by the literary style which is characteristic of the respective narratives. But more important than that is the fact that the two accounts are contradictory with reference to several particular points.

For instance, the order of creation is reversed in the second chapter from what it is in the first. According to one account man is created by the word of God, but in the other one he is manufactured by God from the dust of the ground. The first chapter tells us that woman was created at the same time as man and furthermore she was created as his equal. But in the second chapter we find that woman was created later than man. She was made from one of his ribs, and was created for an helpmate rather than his equal. Simon found not only two creation stories in Genesis, but several other stories with more than one version. He constructed two distinct and complete narratives of the flood and showed that these contained both differences in style and discrepancies with reference to details in the story. According to one story Noah took into the ark seven of all the clean beasts and two of those that were unclean, but in the other one it says that he took into the ark two of all the creatures including both the clean and the unclean. Again in one story the flood came as a result of the fountains of the deep being broken up but in the other one it was caused by forty days and nights of continual rain. In one account Noah remains in the ark a little more than fifty days but in the other one he remains there a year.

Later on, the fact was brought to light that in the early narratives of the book of Genesis two names are used to refer to the deity. One of these names is Yahweh and the other one is Elohim. In one set of stories the name Yahweh is used consistently throughout, while in the other set the name Elohim is used. Thus in the creation story found in the first chapter of Genesis the deity is called Elohim while in the second creation story the name Yahweh is used. The presence of these two names is all the more significant because they represent different conceptions of the deity. Yahweh is an anthropomorphic god who possesses a body and who talks and acts as a human being would do. He walks in the garden in the cool of the day and talks with Adam about the sin he has committed. He visits Abraham in his tent and partakes of a meal. He goes down to the land of Shinar to see for himself what is going on, and he hides in a cleft of the rock so that Moses cannot look on his face but is permitted to see his back. Elohim does not possess these characteristics. He is a spiritual being who appears to individuals in dreams and whose presence is manifested in the pillar of cloud by day and the pillar of fire by night.

Again if one puts together the material in which the name Yahweh is used it will be found that the names of places and persons which occur are those that pertain to the southern kingdom, while the Elohim material contains names that have reference to the northern kingdom. Thus the name Israel occurs frequently in the Elohim narrative but is absent in the Yahweh stories, while the reverse is true of the name Jacob.

The book of Deuteronomy is attributed to Moses at the beginning of its opening chapters. But a reading of the laws contained within the book reveals a type of legislation which does not fit either the age in which Moses lived or the conditions which prevailed during the first century after his death. For example, some of the laws of Deuteronomy have to do with the tenure of land. One law provides that at the end of every seven years the land that has been taken from the poor in settlement of debt shall be returned to its former owners. Another law provides for a redistribution of the land at the end of every fifty year period. These laws are of course appropriate for a people who are settled permanently in one part of the country. But in the age of Moses and for a long time afterwards the Hebrews had no permanent location. They were shepherds and nomads wandering about from one part of the country to another.

Other laws found in Deuteronomy have reference to a form of government which did not come into existence until centuries after the death of Moses. One of the most prominent laws of the book is what is known as the *Law of the Central Sanctuary*. This law provides that the Hebrews shall offer their sacrifices at one place only, and that no outlying sanctuaries shall be permitted in the land. The purpose of this law was to centralize the worship at one particular place so that foreign elements would not be allowed to corrupt the forms which had become established. Now it can be proved from other parts of the Old Testament that this law was first proclaimed and enforced by the Hebrews in the year 621 B.C. Prior to this time the offering of sacrifices had been permitted at any of the outlying shrines.

If one excludes from the Old Testament books which we have considered, all the material that includes the Yahweh stories, the Elohim narratives, and the central portion of the book of Deuteronomy, it will be found that the remaining material constitutes a fourth complete narrative. This narrative has certain peculiar characteristics including a stately form, a legalistic style of writing, and a dominant interest in the origin of religious rites and ceremonies. The story as a whole is typical of the priestly influence which was dominant among the Hebrews after the return from the Babylonian captivity.

QUESTIONS AND EXERCISES

1. What two views are held today with reference to the authorship of the Pentateuch? Why is this a problem for historical criticism?
2. Summarize the evidence for the Mosaic authorship of these books. Is any of this evidence obtained from the contents of the books? Is it obtained from sources that are reliable?
3. Does the title given to a book prove anything concerning the

authorship of the book? Explain. Mention analogous cases from the literature of the present day.

4. What facts were brought to light by Spinoza? Can these facts be made to harmonize with the idea of Mosaic authorship? With the Documentary Hypothesis?
5. What is the natural inference to be drawn from the facts concerning the two creation stories? The two flood stories?
6. What is the significance of the two names for the deity, Yahweh and Elohim? What characteristics are associated with each name?
7. Why is the legislation contained in the book of Deuteronomy inconsistent with the idea of Mosaic authorship?
8. What was the law of the Central Sanctuary? Why is it inconsistent to attribute this law to Moses?
9. What is the evidence for a late priestly narrative?
10. Can the Documentary Hypothesis present a consistent explanation of all the facts mentioned in this summary, including those given in support of the older view of Mosaic authorship? Explain.

CHAPTER XXI

REASONING IN LAW

Laws of the land are in certain respects similar to the laws of the natural sciences. First of all they are generalizations based upon facts of human experience. They are based upon the general principle of the uniformity of nature. They must be tested and verified by means of repeated applications. And finally, each law must be regarded as a kind of tentative hypothesis, always subject to revision in order to conform more completely with the facts of experience. On the other hand there are certain differences between the laws enacted by a legislative body and the laws which pertain to the natural sciences. The laws of nature do not govern in the sense of *controlling* the phenomena of the physical world. Their function is that of describing rather than regulating things. But the laws of the land are for the purpose of giving direction to human behavior.

Again, the laws on the statute books are man-made laws. Human beings did not find them already in existence. They had to create the enactments. Of course it is true that in one sense the laws of the physical sciences are also made by men. It was as a result of human thinking that they were formulated. But in this case the formulation of the laws was only a description of principles that were already in operation. The laws of the physical sciences are discovered in a sense that is not true of the laws that are enacted by a legislature. Perhaps the most significant difference between these two kinds of law is best indicated by the statement that in the field of law we are dealing with the realm of human values, while in the field of the natural sciences we are dealing only with the impersonal facts of nature.

It is impossible within the limits of a brief discussion to explain or to illustrate all the different types of problems that arise within the legal field. We shall simply call attention to three distinct phases of legal procedure.

The first of these is the process by which laws are originated. We cannot say that the thinking which finally results in the enactment of a law begins with the deliberations of the legislative body that enacts it. Before a bill is introduced into a house of legislators, a person or group of persons have arrived at the conclusion that the bill is a good one and should become a law. The bill thus introduced is a tentative hypothesis. Probably many factors have contributed toward its formation and development. Particular observations have been made and the hypothesis in question seems to be an adequate generalization for meeting the needs in the situations observed. Similarity between the particular situations in mind and other ones that have been properly handled by previous legislation may be another factor. And deductions from generally recognized principles or customs have doubtless contributed something as well. The task before the legislature, after the bill has been introduced, includes working out, by means of deductive reasoning, the implications that are involved in it. The imperfections of the bill will in this way be brought to light and thus an opportunity for making corrections can be given.

A second phase of legal procedure consists in the testing of the validity of laws after they have been enacted by a legislative body. This is essentially the work of the courts. Of course the testing of any law necessarily involves some criterion or standard by which it is judged. Such a standard is provided by the constitution of the state where the law has been passed. Since new conditions are arising all the time there is a constant need for interpreting the meaning or real intent of the constitution. It is the business of the court to determine the meaning of the constitution with reference to the particular situation that is in dispute. If, after careful deliberation, it develops that there is a real conflict between the meaning of the law and the meaning of the constitution with reference to the particular case, the law will be declared invalid.

A third phase of legal thinking may be seen in the application of laws to concrete cases. The procedure for doing this involves a use of the syllogism and is illustrative of the deductive type of reasoning. A statement of the law constitutes in each instance the major premise of the argument. The minor premise is established by the evidence in the particular case, and the conclusion is reached by determining the relation of the two premises. For example, we may take as a statement of the law the proposition, "All thieves shall serve a sentence in jail." We may conclude that the evidence in this case indicates that John Jones is a thief. Therefore, he must serve a sentence in jail.

The argument as thus presented is very simple. The real problem, however, arises in connection with the establishment of the truth of the minor premise. This involves in the first place a procedure for evaluating the testimony or evidence that has been presented. It is of course essential to know the facts if a correct judgment is to be reached. The methods of reasoning employed for determining the facts are similar to the ones used by the historian in the criticism of his source materials. The lawyer, the same as the historian, must be able to put the various pieces of evidence together so as to form a unit which will be not only consistent with itself but in harmony with all other known facts. In the second place, the establishment of the minor premise would, in the example given, involve a definition of stealing. In some instances there would be no question as to whether the specific act was a case of stealing. But in other cases there would be a difference of opinion. The problem could be solved only by considering analogous cases and by a further determination of the real intent of the law.

It is necessary to employ logical methods in dealing with the problems that are peculiar to each phase or division of the legal field. In general it may be said that the solution of any legal problem involves a combined use of the scientific imagination, deductive reasoning, and the inductive methods. There are, however, certain methods which are particularly useful in specific phases of the legal field. For example, the method of analogy is constantly used with reference to the precedent that has been established by former decisions.

Syllogistic reasoning is necessarily used in the application of general laws to specific cases. The weighing of evidence may include the use of any of the inductive methods, but it is the combined method which is likely to be used most frequently. Rival hypotheses are presented by the attorneys on the two sides, and the court or jury must decide which one is correct.

The problems presented in the remainder of this chapter are ones that have to do with the weighing of evidence. Other phases of legal thinking are equally important, but these are selected because they are relatively easy for students who are taking their first course in logic.

I

EIDT *versus* CUTTER

[From *Principles of Judicial Proof,* by J. H. Wigmore. By permission of the author and Little, Brown & Company, publishers]

Tort for injuries to the plaintiff's house and fence, alleged to have been caused by the fumes, vapors and gases escaping from the defendant's copperas works, and discoloring the paint on the house and fence.

At the trial in the Superior Court, before Dewey, J., it appeared that the premises of the parties were in the southerly part of the city of Worcester, and in close proximity to an open sewer maintained by the city ; and there was evidence tending to show that from this sewer and from the piles of filth dug from it and laid on its banks, there were foul exhalations of gases containing ammoniacal salts. The evidence of the defendant's experts tended to show that the gases and substances escaping from the copperas works should not of themselves produce the discoloration visible on the plaintiff's house, but that the discoloration as seen was produced by the union of the gases and substances from the defendant's works with the ammoniacal gases escaping from the sewer. The defendant's experts testified that coppers deposited on a painted surface did not break through or abrade the paint. They exhibited to the jury a board, upon which they had atomized copperas in large quantities. The color of the board had been changed but when the copperas was brushed off, the painted surface was shown to be intact beneath. This experiment was offered only to show the fact that copperas did not penetrate paint.

The evidence of the plaintiff's experts tended to show that the condition of the plaintiff's house and fence could be, and was, brought about by the gases and substances coming from the defendant's works; that the gases coming from the open sewer probably accelerated and intensified the effect, but that there is a sufficient quantity of ammonia in ordinary atmosphere to account for the present discoloration. These experts stated that they formed their judgments from their general knowledge of chemistry, from experiments heretofore made, and from a series of experiments recently made by them, both at the house of the plaintiff, and in the city of Providence, Rhode Island, and elsewhere.

The experiments made at the house of the plaintiff were upon boards, papers, etc., exposed for six weeks to the atmosphere, and to the fumes, vapors, and substances therein contained, and were acted upon thereby under the same circumstances and conditions as the plaintiff's house during the time they remained on the house. The experiments made at Providence and elsewhere consisted mainly of atomizing copperas upon boards, papers, glass, etc., and exposing the same to the atmosphere and were made under conditions and circumstances which, as the plaintiff's experts stated, were, in their opinion, as near like those surrounding the plaintiff's house, in the absence of the sewer, as was possible, and were made for the purpose of ascertaining the effect of copperas gases where the atmosphere was otherwise pure. The boards, papers, etc., thus used by the witnesses of the plaintiff in these experiments were brought into court and exhibited, and explained to the jury, and a detailed account of the experiments given to the jury by the witnesses.

The defendants objected to the introduction before the jury of any of the experiments, and the evidence given explanatory thereof, made by the plaintiff's experts at Providence, Rhode Island, and at other places other than at the plaintiff's house. The judge admitted these last named experiments and the evidence relating thereto, on the ground that the experts, having first stated their judgment as to the character and effect of the gases and substances from the defendant's works alone, and when in union with ordinarily pure air, and when in union with the gases coming from the city sewer, might state the grounds on which they based their judgment; and, they having stated that, among other things, the grounds on which they based their judgment were certain experiments made by them, the judge allowed the witnesses to testify as to the experiments made by them, limiting them to the statement of the experiments on which they said they had, in part, based the judgment and opinion to which they had testified.

The jury returned a verdict for the plaintiff; and the defendants alleged exceptions.

By the Court. The question in controversy, and upon which both parties had introduced the testimony of experts was whether the injury to the plaintiff's house was caused by the fumes and gases from defendant's works, or by the emanations from a sewer. The grounds and reasons of the opinions of the experts, including the details of experiments made by them under conditions and circumstances which, as they testified, were nearly as possible like those surrounding the plaintiff's house in the absence of the sewer, were rightly permitted to be stated by the experts, in order to assist the jury in understanding their testimony and applying it to the case. Lincoln v. Taunton Copper Co., 9 Allen 181. Commonwealth v. Piper, 120 Mass. 185, 190. Williams v. Taunton, 125 Mass. 34. Exceptions overruled.

QUESTIONS AND EXERCISES

1. What logical method was used by the plaintiff to prove that the injury to his house and fence had been caused by the gases escaping from the defendant's copperas works? Explain the way in which this method was used.
2. How was the plaintiff's argument attacked by the defendants in their attempt to prove that his conclusion was unsound?
3. What evidence was offered by the defendants to prove that copperas, unless mixed with ammonia, will not penetrate or alter the color of paint? What logical method did they use in this argument?
4. How was this argument attacked by the plaintiff?
5. Upon what deductive inferences did the plaintiff's experts base their claim that the gases escaping from the defendant's copperas works is sufficient when mixed with ordinary atmosphere to damage the paint on the plaintiff's property?
6. Show how these deductive inferences were reinforced by inductive considerations based on a series of experiments performed by the plaintiff's experts. What inductive method was used in these experiments to determine the effects of copperas in the absence of the city sewer? What conclusion was reached?
7. On what grounds did the defendants object to the introduction

of testimony which was based on the experiments performed by the plaintiff's experts?

8. Why were these objections overruled in the higher court?
9. What bearing did the three cases referred to by the higher court have on the validity of the testimony which was offered in this case? What type of reasoning is involved here?

II

STARNE COAL CO. *versus* RYAN

[From *Principles of Judicial Proof*, by J. H. Wigmore. By permission of the author and Little, Brown & Company, publishers]

Opinions of the Court, the Hon. Carroll C. Boggs, Judge. The appellee, while in the employ of the appellant company as a driver for coal cars on a track in its mine, was thrown from a car and injured. This is an appeal from a judgment in his favor because of such injuries. The declaration contained three counts, the gravamen of the charge in each that the appellant company negligently suffered a portion of the track of its road in the mine to become and remain in bad and unsafe repair and condition, and that by reason thereof the car upon which the appellee was riding left the track, causing the injuries complained of. . .

The injury was received at a point where the track passed upon a somewhat descending grade, through a rather dark entry. The appellee was driving a mule hitched to a train of three cars, upon the front one of which he was riding. He came down the track at a rather rapid rate, the mule, according to the testimony, being in a "lope" when the car "jumped" the track and threw him against one of the props of the mine. He had been employed as a driver in this mine for some ten months and had been driving through the entry in which he was hurt for three weeks, during which time he passed and repassed frequently over the place where he was hurt, often passing there, as he testified, fifteen to twenty times per day. On the day that he was hurt he began to work at 7:30 in the morning, passed the place in question seven times, and was passing it for the eighth time when the accident occurred. His testimony was that he observed nothing wrong with the track during any of the trips prior to the last one, and he thinks there was nothing wrong before that; that the car jumped the track because the end of one of the rails of the track was turned in at the joint; that it could not have been in that condition when he passed there on the preceding trips, nor when another driver passed over it in advance of him, or that the driver would have been thrown off. . . The appellee contended that the tie, upon which the rail rested and to which it ought to have been securely nailed, was defective and insufficient to hold the nails of the rail, and for that reason the rail was moved from its place at the end where it should join the next rail.

To support this contention and as the only evidence in its support, the appellee sought to show that immediately after he was injured and before the cars from which he fell were moved, a new tie was placed in the track. From this, if true, it might reasonably be inferred that the track was unsafe with the ties already there, and that another tie was necessary to put the track in good and safe condition for use. Upon this point, in behalf of the appellee, J. R. Burns testified that he saw Michael Lynch, appellant's roadmaster, putting a tie in the track immediately in the rear of the car that left the track, before such car was moved after the accident; and Michael Laundregan, also a witness for the appellee, testified that he saw Lynch there at the time with a tie in his hands and that he seemed to be working at the track. This was all testimony favorable to the appellee on this point.

Lynch testified that he went at once to the place of the accident, found two cars off the track, replaced them, examined the track and the iron rails carefully to see that they were safe for use, and found them in good condition; that he had a wooden gauge used for ascertaining whether the track was level, and that he and Michael Hickey, who was assisting him, placed this gauge upon the track to see that it was level; that he had no tie there; did not find it necessary to use one; and did not use one; that the rail was not bent nor turned in at the joint, but that the track was in good and safe condition for use, and they began at once and continued hauling cars over it after the accident as before.

John Hickey, a coal miner, stated, as a witness, that he was with Lynch, assisting in the work, and remained with him until the cars were running again over the track; that he examined the track and the rails, testing the rails carefully with a hammer; that there was nothing wrong with either; that he and Lynch gauged the track and found it level; that no tie was removed, nor was a tie put in the track; that it was not necessary to put one in; that the cars were hoisted on the track and the track used at once for the passage of cars.

George Courdice, engineer of the mine, and Comack Cunningham, official state inspector of mines, officially examined the track at the place in question the next day after the appellee was injured. Both testified that the track was in good and safe condition; that they saw nothing to indicate that a tie had been placed in the track, and that if such had been done, indications of the work would have been found; that there were no such indications. Both joined in the opinion that no tie had been placed in the track. The state inspector, with a lamp and hammer, examined carefully the rail and spikes by which it was attached to the ties, and could find nothing indicating that any change had been made in the track, the rail or the ties.

We do not think that, under this evidence, the jury were warranted in finding that a tie was placed in the track, as claimed. Such a conclusion seems to be manifestly against the greater weight of the testimony. It would appear more reasonable to conclude that Burns, in the darkness of the entry, mistook for a tie the gauge which Lynch and Hickey were using, than to conclude that both Lynch and Hickey wilfully and knowingly testified falsely, and that they did break the ground and place a tie in the track, in such a manner as to leave no discernible trace of the work. If this view is correct, the evidence fails to show that the injury received by the appellee was occasioned by the failure of the appellant company to discharge its duty toward the appellee as its employee in the respect charged in the declaration. In the absence of such proof there can be no recovery.

QUESTIONS AND EXERCISES

1. What method of reasoning did the plaintiff use in the lower court to prove that his injury had been caused by a defective tie? Explain fully the way in which this method was used.
2. What evidence was offered, in the appellate court, by the defendants, to prove that the plaintiff's explanation was false?
3. What explanation concerning the cause of the plaintiff's injury was implied in the testimony offered by the defendant's witnesses?
4. When two rival hypotheses are offered in explanation of a given set of circumstances, how are we to decide between them?
5. In the case before the court, which hypothesis was supported by the greater amount of evidence?
6. Show how, on the supposition that the plaintiff's witness had mistaken for a tie the gauge which Lynch and Hickey were using, it was possible to bring the facts offered by each party into

harmony with each other. Why are there good reasons for making the supposition referred to above?

III

LIST PUBLISHING CO. *versus* KELLER

[From *Principles of Judicial Proof*, by J. H. Wigmore. By permission of the author and Little, Brown & Company, publishers]

In Equity. Bill for injunction to restrain infringement of complainant's copyright.

Wallace MacFarland, for complainant. Edmund Wetmore, for defendant. Wallace, ———. The parties are the proprietors and publishers of rival "society" directories, which purport to give the names and addresses of those persons in New York City who are supposed to be people of fashion. The complainant asserts that its copyrighted directory, "The List," is infringed by the defendant's directory, the "Social Register," and has made a motion for a preliminary injunction. The question in the case is whether the defendant, in compiling his directory, has done so by his own original labor, or whether in order to spare himself time and expense, he has copied the names and addresses given in the "Social Register" from the "List." If he has copied any part of the complainant's book, he has infringed the copyright. He has no right to take, for the purpose of a rival publication, the results of the labor and expense incurred by the complainant, and thereby save himself the labor and expense of working out and arriving at these results by some independent road. . . The compiler of a general directory is not at liberty to copy any part, however small, of a previous directory, to save himself the trouble of collecting the materials from original sources. . . Either of the present parties could lawfully use the general city directory to obtain the correct addresses of the selected persons; nor is it doubted that the defendant had the right to use the complainant's book for the purpose of verifying the orthography of the names, or the correctness of the addresses, of the persons selected. But if the defendant had used the "List" to save himself the trouble of making an independent selection or classification of the persons whose names appear in the "Social Register," although he may have done so only to a very limited extent, he has infringed the complainant's copyright.

In a case like this, when a close resemblance is the necessary consequence of the use of common materials, the existence of the same errors in the two publications affords one of the surest tests of copying. The improbability that both compilers would have made the same mistakes, if both had derived their information from independent sources, suggests such a cogent presumption of copying by the later compiler from the first that it can be overcome only by clear evidence to the contrary. Mawman v. Tegg, 2 Russ. 393; Spiers v. Brown, 31 Law T. 16; Lawrence v. Dana Law T. (N. S.) 402. The complainant relies upon this criterion here. The "List" contains a selection of about 6000 names and addresses of persons residing in New York City out of the 313,000 names which appear in the general city directory. The "Social Register" contains about 3500 names and addresses of persons residing in New York City, and of this number over 2800 appear in the "List." The fact that 2800 of the names and addresses in the defendant's book originally appeared in the complainant's book would, standing alone, be quite inconclusive. But when it is shown that 39 errors in the complainant's book, consisting of misprints, erroneous addresses, insertion of names of people who never existed, and insertions of names of deceased persons, are reproduced in the defendant's book, although it was not published until more than a year after the complainant's book was published, a strong presumptive case of piracy is made out.

The depositions on the part of the defendant are addressed in part to an explanation of his reproduction of these errors consistently with the theory that they were not copied from the complainant's book. These depositions have been carefully read and considered, and the conclusion has been reluctantly reached that the explanation is inadequate. It will not be profitable to analyze the depositions. It suffices to state that the case for the complainant is the part of the defendant. If it is true that his directory was prepared from several private visiting lists furnished to Ashmore for the purpose, these lists should have been produced or their non-production accounted for; and, if they could not be produced, corroborative testimony of their existence, the sources from which they were obtained, and their contents should have been adduced. It may be that the presumption which at present must prevail will be overthrown by the proofs at the final hearing of the case, but, as the case now appears, the complainant is entitled to an injunction. The injunction will be limited to the extent to which the defendant's book is identical with the complainant's book.

QUESTIONS AND EXERCISES

1. What precisely is the point at issue in this case? Explain briefly the nature of the logical problem involved in finding a true explanation of the phenomenon being investigated.
2. An explanation for the names in the "Social Register" is offered by both the plaintiff and the defendant. State, as best you can, the evidence by which each of these explanations is supported.
3. "The existence of the same errors in the two publications affords one of the surest tests of copying." This principle is assumed in the case under consideration. What logical ground or reason can you give for this assumption?
4. Why was the plaintiff's hypothesis accepted by the court, and the defendant's hypothesis rejected?

CHAPTER XXII

REASONING IN ETHICS

ETHICS is the study of human conduct in so far as this conduct is judged to be right or wrong. Since the terms "right" and "wrong" are applicable only to the voluntary acts of human beings, the science of ethics is limited to this sphere. Unlike the physical and the biological sciences the purpose of ethics is not to describe phenomena but to evaluate them. It aims to answer the question "What actions can be called good?" To do this, consideration is given not alone to conditions as they actually exist but to the ideal which may or may not be realized. In other words ethics is concerned not only with "what is" but with "what ought to be."

Although the field of ethics is distinct from that of all the other sciences it has one thing in common with them. Logical thinking is as necessary for ethics as for any of the other fields of knowledge. There is no special way of arriving at truth in this particular realm. The fact that human beings do, as a general rule, follow the customs of the group to which as individuals they belong does not prove that these customs are right. We do know that in many instances customs have been wrong. Hence if we wish to be intelligent concerning the moral quality of some act we must be guided by something other than custom. Sometimes people have appealed to "conscience" as the final arbiter or judge of what is right and wrong. Conscience is an important factor in human life, and it is never right for one to act contrary to the best judgment that he possesses. Nevertheless the voice of conscience is no infallible guide to a knowledge of the requirements of goodness. This is proved by the fact that the conscience of one person is often in disagreement with the conscience of another. Furthermore, an individual's own conscience frequently changes from time to time. Again, we cannot answer the question "What is right?" by appealing to some external authority. To argue that a given course of conduct is right because some individual, or book, or ecclesiastical authority says so, is to be guilty of the fallacy of *argumentum ad vercundiam.* Authorities, no less than the private consciences of individuals, may conflict with one another. Besides, there is the added problem of knowing which authority one should accept.

Since we cannot determine the content of the science of ethics by studying customs, or by an appeal either to conscience or to any external authority, it follows that the truths which belong to this field must be established by using the methods of correct thinking. Logical methods applied to the study of the data which belong to this field is the only way to build up a science of ethics. In this field, as in all the other branches of human knowledge, the only authority that can rightfully be recognized is the authority of reason.

From the standpoint of logic, the study of ethics is concerned with two main problems. The first one is the discovery of a satisfactory standard or criterion of goodness. And the second one is the application of this standard to concrete cases. The first of these problems can be solved only by using the methods of thinking that are involved in the formation and verification of hypotheses. It is necessary to accept tentatively some theory or hypothesis and then to proceed, by means of deductive reasoning, to work out the implications that are involved in it. In this way the meaning of the hypothesis with reference to particular situations can be brought to light.

If these deductions reveal inconsistencies between the different parts of the theory, or if it is evident that they contradict either the fundamental assumptions of morality or the facts of human experience, then the theory must be rejected. Or, at least it must be modified so that these difficulties can be overcome. The solution of the second problem frequently involves an evaluation of alternative courses of action with the purpose of determining which one contributes more toward the realization of the desired end or goal. It is at this point that a knowledge of the laws and principles of other sciences than ethics becomes relevant.

If I wish to have a healthy body and a well-developed mind, I can achieve this goal only by choosing those things which produce that end. In other words, I must act in accordance with principles that belong to the fields of physiology and mental hygiene. Or if my purpose is that of promoting the welfare of society, it is necessary to employ those principles which are consistent with that end.

In a previous discussion of the nature of the physical sciences and the methods of thinking by which they are developed, it was pointed out that these sciences are based upon certain logical assumptions. The uniformity of nature and the laws of thought are necessary assumptions for any body of scientific knowledge. If we assume these principles to be true, then we can discover laws of nature and make predictions concerning the behavior of things in the future. Now in addition to the assumptions upon which the physical sciences are based, ethics has another postulate. It is the postulate of freedom. There is no way of proving experimentally that human beings can make choices or that they cannot make them. But we do know that the ability to make choices is a necessary condition of any moral experience. So, in the absence of any facts which prove the contrary, we believe that we are warranted in making this assumption.

Since ethics is concerned with problems that have to do with human values, it is quite obvious that in the majority of cases we cannot rely upon experimentation as a means of verifying our hypotheses. From one point of view it is impossible to construct a social experiment since we cannot control conditions as we do in the laboratory sciences. This does not mean that we can never test ethical hypotheses by an appeal to human experience. We should, in fact, use this test whenever it is possible to do so. Usually, however, we must employ another kind of test in addition to this one. This is the test of consistency. To do this we must determine whether the implications of our hypotheses are free from contradiction either with each other or with known facts.

As an example of correct thinking in the field of ethics we will consider first an argument taken from Plato's dialogue called *Laches*. It is an illustration of the *dialectical* method which was employed by Socrates for the purpose of discovering the real nature of the virtues.

I

THE MEANING OF COURAGE

[Selected and abridged from Plato's *Laches*]

Socrates. Then, Laches, suppose that we first set about determining the nature of courage. Tell me if you can, what is courage.

Laches. Indeed, Socrates, I see no difficulty in answering; he is a man of courage who does not run away, but remains at his post and fights against the enemy; there can be no mistake about that.

Socrates. You would call a man courageous who stays at his post and fights the enemy. So would I. But what would you say of a man who fights while he is in pursuit of the enemy? Does he possess courage?

Laches. Certainly. But now you are speaking of those who fight in chariots; they have a certain way of fighting. But the heavy-armed Greek fights, as I say, remaining in his rank.

Socrates. And yet, Laches, you must except the Lacedaemonians who when the ranks of the Persians were broken turned upon them like cavalry, and won the battle of Plataea.

Laches. That is true.

Socrates. I meant to ask you not only about the courage of the heavy armed soldiers, but about the courage of cavalry and every other style of soldier; and not only who are courageous in war, but who are courageous in perils by sea, and who in disease, or in poverty; or again in politics are courageous; and not only who are courageous against pain or fear, but mighty to contend against desires and pleasures. There is this sort of courage — is there not, Laches?

Laches. Certainly, Socrates.

Socrates. Now I was asking about courage and cowardice in general. What is that common quality, which is the same in all these cases, and which is called courage?

Laches. I should say that courage is a sort of endurance of the soul, if I am to speak of the universal nature of them all.

Socrates. But that is what we must do if we are to answer the question. I am sure, Laches, that you would consider courage to be a very noble quality.

Laches. Most noble, certainly.

Socrates. But what would you say of a foolish endurance? Is not that to be regarded as evil and hurtful?

Laches. True.

Socrates. And is anything noble which is evil and hurtful?

Laches. I ought not to say that, Socrates.

Socrates. Then according to you, only the wise endurance is courage?

Laches. True.

Socrates. But wise in what? If a man shows the quality of endurance in spending his money wisely, knowing that by spending he will acquire more in the end, do you call him courageous?

Laches. Assuredly not.

Socrates. Again take the case of one who endures in war, and is willing to fight, and wisely calculates and knows that others will help him, and that there will be fewer and inferior men against him than there are with him; — would you say of such a one, or some man in the opposing army who is in the opposite circumstances to these and yet endures and remains at his post, is the braver?

Laches. I should say the latter.

Socrates. But, surely, this is a foolish endurance.

Laches. That is true.

Socrates. But foolish boldness and endurance appeared before to be base and hurtful to us, whereas courage was acknowledged to be a noble quality. And now on the contrary we are saying that the foolish endurance is courage. Can we be right in this?

Laches. Indeed, Socrates, I am sure that we are not right.

Socrates. Let us invite Nicias to join us. Come, Nicias, tell us what you think about courage.

Nicias. I have often heard you say that 'Every man is good in that in which he is wise, and bad in that in which he is unwise.' And, therefore, if the brave man is good, he is also wise.

Laches. I would like him to say what is the nature of this knowledge or wisdom.

Nicias. I mean to say, Laches, that courage is the knowledge of that which inspires fear or confidence in war, or in anything.

Laches. Surely, courage is one thing and wisdom another. Do not physicians know the dangers of disease? or do the courageous know them? or are the physicians the same as the courageous?

Nicias. Not at all. The physician's knowledge extends only to the nature of health and disease; he can tell the sick man no more than this. Do you imagine that the physician knows whether health or disease is the more terrible to a man? And do you suppose that the physician or any other artist knows this, except he who is skilled in the grounds of fear and hope? And him I call the courageous.

Socrates. He who assents to your doctrine cannot allow that any wild beast is courageous.

Nicias. I do not call animals or any other things which have no fear of dangers, because they are ignorant of them, courageous, but only fearless and senseless. I am of the opinion that thoughtful courage is a quality possessed by very few, but that rashness and boldness, and fearlessness which has no forethought, are common qualities possessed by many.

Socrates. I must beg of you, Nicias, to begin again. You remember that we originally considered courage to be a part of virtue. Do you agree with me about the part? For I say that justice and temperance, and the like are all of them parts of virtue as well as courage. Would you not agree?

Nicias. Certainly.

Socrates. But then, my dear friend, if a man knew all good and evil, and how they are, and have been, and will be produced, would he not be perfect, and wanting in no virtue, whether justice, or temperance, or holiness? He would possess them all, and he would know which were dangers and which were not, and guard against them whether they were supernatural or natural; and he would provide the good, as he would know how to deal both with gods or men.

Nicias. I think, Socrates, that there is a great deal of truth in what you say.

Socrates. But then, Nicias, courage, according to this new definition of yours, instead of being a part of virtue only, will be all virtue.

QUESTIONS AND EXERCISES

1. What is the field of ethics? Why is it impossible to solve problems in this field by an appeal to conscience? by reference to some external authority?
2. From the point of view of logic, what are the two main problems with which the study of ethics is concerned? Discuss briefly the logical procedure for dealing with each of these.
3. What is meant by "the postulate of freedom"? What is the logical ground or basis for this postulate?

4. What is the procedure for testing or verifying an ethical hypothesis? Why is it imposible to employ experimentation in this field as we do in other fields of science?
5. Describe the dialectical method of reasoning as it was employed by Socrates in his search for a true definition of courage.
6. What was the first definition of courage given by Laches? What was Socrates' objection to it?
7. From the dialogue we gather that Socrates was searching for a universal "form" or definition of courage. Why did Socrates believe that a search of this kind was necessary?
8. How did Socrates refute the assertion that courage is an "endurance of the soul"? a wise endurance of the soul?
9. Explain the position of Nicias that courage is a species of knowledge.
10. How does Socrates modify this definition? What conception of courage is finally reached?

II

ARISTOTLE'S CONCEPTION OF THE GOOD

[These selections are taken from Aristotle's *Ethica Nicomachea* translated by W. D. Ross]

Every art and every inquiry, and every action and pursuit is thought to aim at some good; and for this reason the good has rightly been declared to be that at which all things aim.

If, then, there is some end of the things we do, which we desire for its own sake, and, if we do not choose everything for the sake of something else (for at that rate the process would go on to infinity, so that our desire would be empty and vain) clearly this must be the good and the chief good. Will not the knowledge of it, then, have a great influence on life? Shall we not, like archers who have a mark to aim at, be more likely to hit upon what is right?

* * *

Let us again return to the good we are seeking and ask what it can be. It seems different in different actions and arts; it is different in medicine, in strategy, and in the other arts likewise. What then is the good of each? Surely that for whose sake everything else is done. In medicine this is health, in strategy victory, in architecture a house, in any other sphere something else, and in every action and pursuit the end; for it is for the sake of this that all men do whatever else they do. Therefore, if there is an end for all that we do, this will be the good achievable by action, and, if there are more than one, these will be the goods achievable by action.

Presumably, however, to say that happiness is the chief good seems a platitude, and a clearer account of what it is, is still desired. This might perhaps be given if we could first ascertain the function of man. For just as for a flute-player, a sculptor, or any artist, and in general, for all things that have a function or activity, the good and the 'well' is thought to reside in the function, so would it seem to be for man, if he has a function. . . What then can this be? Life seems to be common even to plants, but we are seeking what is peculiar to man. Let us exclude, therefore, the life of nutrition and growth. Next there would be a life of perception, but *it* also seems to be common even to the horse, the ox, and every animal. There remains then an active life of the element that has a rational principle. . . Human good turns out to be activity of soul in accordance with virtue, and if there are more than one virtue, in accordance with the best and most complete.

But we must add 'in a complete life.' For one swallow does not make a summer, nor does one day; and so too one day, or a short time does not make a man blessed and happy.

Let this serve as an outline of the good; for we must presumably first sketch it roughly, and then later fill in the details.

* * *

From this it is also plain that none of the moral virtues arises in us by nature; for nothing that exists by nature can form a habit contrary to its nature. Again, of all the things that come to us by nature we first acquire the potentiality and later exhibit the activity; but the virtues we get by first exercising them, as also happens in the case of the arts as well. For the things we have to learn before we can do them, we learn by doing them, e.g., men become builders by building and lyre-players by playing the lyre; so too we become just by doing just acts, temperate by doing temperate acts, brave by doing brave acts.

Again it is from the same causes and by the same means that every virtue is both produced and destroyed, and similarly every art; for it is from playing the lyre that both good and bad lyre-players are produced. . . This then is the case with the virtues also; by doing the acts that we do in our transactions with other men we become just or unjust, and by doing the acts that we do in the presence of danger, and being habituated to feel fear or confidence, we become brave or cowardly. . . Thus in one word states of character arise out of activities. This is why the activities we exhibit must be of a certain kind; it is because the states of character correspond to the differences between these. . .

Now that we must act according to the right rule is a common principle and must be assumed. But it must be agreed upon beforehand that the whole account of matters of conduct must be given in outline and not precisely. Matters concerned with conduct and questions of what is good have for us no fixity, any more than matters of health. The general account being of this nature, the account of particular cases is yet more lacking in exactness; for they do not fall under any art or precept, but the agents themselves must be in each case what is appropriate to the occasion as happens also in the art of medicine or navigation.

But though our present account is of this nature we must give what help we can. First, then, let us consider this, that it is the nature of such things to be destroyed by defect and excess, as we see in the case of strength and of health; both excessive and defective exercise destroys the strength, and similarly drink or food which is above or below a certain amount destroys the health, while that which is proportionate both produces and increases and preserves it. So too is it, then, in the case of temperance and courage and the other virtues. For the man who flies from and fears everything and does not stand his ground against anything becomes a coward, and the man who fears nothing at all but goes to meet every danger becomes rash; and similarly the man who indulges in every pleasure and abstains from none becomes self-indulgent, while the man who shuns every pleasure, as boors do, becomes in a way insensible; temperance and courage, then, are destroyed by excess and defect, and preserved by the mean.

QUESTIONS AND EXERCISES

1. State briefly and in your own words, Aristotle's argument for the existence of a *summum bonum* or highest good. Is a concept of this kind necessarily implied in every use of the term "good"?
2. Why must the highest good always be regarded as an end and never as a means to an end? State the argument in terms of the hypothetical syllogism.
3. Why is it impossible to regard wealth or good fortune as the good?
4. What analogies are used by Aristotle in support of his conception of the highest good for man?

5. Why does he select man's rational nature in preference to the physical or animal side of his nature?
6. What argument does Aristotle use to prove that virtues are not present in us by nature?
7. What does Aristotle mean by a "good character"? How can it be developed?
8. Is ethics an exact science? Give reasons for your answer. If it is not an exact science of what use is it?
9. What is the essential meaning of the doctrine of the golden mean? In accordance with this principle how would you define the virtue of temperance?
10. Make several deductions from Aristotle's general principle so that its meaning with reference to specific situations will be apparent.
11. How, from the logical point of view, would you proceed to test the validity of Aristotle's doctrine?

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